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ABSTRACT

Experts from the fields of law, business, government, and research were invited to a symposium sponsored by Dartmouth College to examine public policies which are challenged by the advent of computer technology. Eleven papers were delivered addressing such critical social issues related to computing and public policies as the man-computer relationship, electronic funds transfer, computer models and simulation, computers and political effectiveness, computer networks, risk taking, and rights and abuses. (CMV)

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Proceedings of the Symposium

Man and the Computer

Edited by Teresa Oden
and Christine Thompson

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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Foreword

Ten years ago, as part of the dedication of the Kiewit Computation Center, Dartmouth sponsored a symposium in which visionary educators and technological experts attempted to predict the future impact of computers. At that time computers were viewed as magic boxes housed behind glass walls and attended by people speaking strange tongues. Computers were enveloped in an aura of mystery, and approached with feelings of fear and awe. In 1966 John Kemeny (now president of Dartmouth College) made what at the time appeared to be an outrageous prediction: by 1990 computer terminals would be as common in the home as televisions were in 1966. Since then computers have moved from behind glass walls to automobiles, supermarkets, airline reservation desks, and 24-hour banks. Interactions with computers in our daily lives have multiplied tremendously and now seem quite commonplace. Institutions such as Dartmouth College have played a significant role in the demystification of computers and their promotion as man's symbiotic partner. The increased computerization of our daily affairs, coupled with the rapid pace of technological advances in this area suggest to me that John Kemeny's prediction may have been too conservative: I predict that by 1990 *computers* (not just computer terminals) are likely to be commonplace in many American homes.

The movement of computers from the marketplace to the home is likely to have far-reaching effects on innumerable aspects of society. Computers hold the potential for tremendous benefits, but their use is also fraught with alarming risks. This dichotomy challenges us to assess existing policies regarding the current and potential uses of computers and to develop new policies in areas where computers are likely to affect existing or evolving social institutions.

Recognizing the fragility of the balance between the benefits of computing and its risks, we at Dartmouth decided to sponsor a second symposium as part of our celebration of the tenth anniversary of the Kiewit Computation Center. To this symposium we invited experts from the fields of law, business, government, and research to re-examine public policies which are challenged by the advent of computing. We asked them to assess the effects computing has had and will have on our daily lives. We felt that Dartmouth's pioneering work in developing an internationally known educational time-sharing system, its success at integrating computing into all aspects of the institution's life, and its many innovative approaches to computing made the College a particularly appropriate place for examining these pressing issues.

Eleven papers were delivered at the symposium on "Man and the Computer" — eleven different views of the critical social issues related to computing and public policy which confront us today. It is our hope that these proceedings will serve to stimulate further examination and discussion of these issues and to influence the development of public policies which will insure that the partnership between man's judgment, intuition, and insight, and the machine's processing speed will be of lasting benefit to society.

John S. McGeachie
Director, Kiewit Computation Center

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ABSTRACT

What will we require in order to achieve a fruitful symbiotic relationship between human beings and computers, as computer technology advances and the size of the user community increases? Three needs are discussed: new user-designed, higher level languages, with tolerance for errors and ambiguity; new methods for updating and retrieving information from the huge and complex data bases to come; philosophical breakthroughs on the question of the optimal division of labor between machines and man.

Keynote Address: The New Symbiosis

JOHN G. KEMENY
President, Dartmouth College
Hanover, NH

During John McGeachie's introduction, I was doing a little bit of reminiscing myself, and it occurred to me what an incredible advantage Tom Kurtz and I had over future generations of computer scientists. Just as he described the advantage of the freshmen over the experienced faculty members, Tom and I had the enormous advantage of never having had any course on computers at all, which is probably why it was so much easier for us than it was for later generations.

On this occasion I can't help thinking back to what happened ten years ago, and I remember vividly my participation in the original dedication ceremony for Kiewit. That was the occasion on which I came out with the outrageous prediction that within twenty-five years computer terminals would be as common in the home as television sets were in 1966. That computer terminals will be common in the home, I think, is not a controversial issue. One does want to take a look at whether the time schedule predicted was correct or not. I remember saying at that time that I had picked that particular date of twenty-five years because I thought technology would make it possible in fifteen, but mankind would surely take at least an extra ten years to achieve that which is possible and desirable. And I think for those two reasons the date 1990 still looks like a good target date.

As I think over what has happened in the past decade — still part of my reminiscing — I think we were quite wrong in under-predicting progress in some areas and being overly optimistic about progress in other areas. For example, the incredible developments having to do with computer logic and with computer memories we certainly did not predict ten years ago. The fact that logic would become almost free, or that at ridiculously small cost one could get enormously complex logical systems, I certainly did not foresee. As to developments in memories, we just had vague ideas of what would happen.

I remember one bottleneck I then identified that seemed to me the easiest one to solve: namely, getting an inexpensive general-purpose terminal. Ironically, as best as I can tell, a general-purpose terminal is slightly *more* expensive today than it was ten years ago, and no progress at all has been made in that area. It gets to be slightly ridiculous when one can have a hand-held, programmable calculator of quite high quality for a cost less than that of a simple, "stupid" typewriter that can talk to a computer. So progress has been somewhat uneven in this decade.

One must also consider the most recent developments: the coming of minicomputers and the coming of the whole computer hobby movement — very important developments — and the question whether these will help or hinder the kinds of things I was dreaming about a decade ago. My current conclusion is that these will certainly help in the long run, but they will hinder progress in the short run. The reason why they will help, I think, is very obvious: many more people are conscious of the existence of computers, many more of them will have hands-on experience, even in their own homes or their own offices. On the other hand, I think these movements will delay the development of major national computer networks, which I see as an absolutely necessary and important development in the long run.

Now minis may play, in the long run again, a terribly important role in any configuration. On the other hand, the kind of cooperation between man and machine that minis make possible is, to use a phrase from my book, a "symbiotic relation" that would be a symbiosis of a lower order than the one I was dreaming of. That is what worries me. Having your own mini — I have had the pleasure of trying one out recently and it is a marvelous machine — gives you a great feeling of power and considerable satisfaction. But it cuts you off from one of the major benefits of what computers ought to be bringing to mankind, namely, the ability to share common data bases, and, more importantly, to share common techniques. I look forward to a new kind of human evolution where, with the means of computers, one *can* have all of human knowledge shared almost simultaneously. I think the movement of everyone owning his or her own separate computer without the national network is in a sense a step in the wrong direction.

THE NEW SYMBIOSIS

My theme today is the New Symbiosis. I know that on important occasions like this it is very important to document one's talk with appropriate quotations from distinguished experts in the field. Therefore I have selected some for this particular presentation from a famous mathematician and logician. I'd like to start with a quote which deals with the subject of symbiosis. Some of you may recognize the quotation.

"Oysters," said the Carpenter,
"You've had a pleasant run!
Shall we be trotting home again?"
But answer came there none —
And this was scarcely odd, because
They'd eaten every one.

That quotation from a very, very famous poem is, I believe, what the average person sees as the outcome of a strong symbiotic relationship between computer and man. The computer plays the role of the walrus and the carpenter, and we are the oysters.

I want to ask the question, "What is necessary to achieve a really fruitful symbiotic relationship where we are not the oysters?" I'm certainly not going to attempt in one relatively short talk to give you an exhaustive overview. Therefore I've selected three problems on which I'd like to concentrate. First, the development of languages. Secondly, there is the problem of use of memory and searches within memories. And thirdly, the problem that I have probably thought most about, and about which I have the least to say because I still find it a puzzling problem, namely, what ought to be the best division of labor between machines and human beings.

LANGUAGE

Problem one: the problem of language. I'm sure that there are many of you in this particular audience who still remember when we had to do all our programming in machine language. Although I'm sure we found it very exciting at the time, it was really a horrible experience and the coming of user languages was one of those great steps forward — first FORTRAN, then a number of other languages including BASIC. I would like to argue, as others have also, that we are going to a very wide use of computers and it will be important to make significant progress with higher level languages. I'm going to argue that for two entirely different reasons, and indeed they will require different kinds of higher level languages. First, for the development of systems software, because I certainly do not believe that as one goes on to write enormous software systems one can continue to go back to machine languages. Secondly, in order to achieve reasonable communication. Remember I'm talking about a national network that may have fifty million users on it, and therefore I'm talking about a group of users with less sophistication and more fear and distrust of computers than anything we have experienced in the past.

As one looks at the higher level languages that have been developed, one realizes that they are of various types; many of them are extremely nice and useful, but they tend to be either highly specialized languages or they attempt to be horribly general. Consider two local examples of very useful special-purpose languages. One is DYNAMO, a language used by people who build models and try to attack problems of society. (Indeed one of the experts on that particular language will be speaking to you later on.) DYNAMO is a very nice language; it is a useful language at a higher level than the ordinary user language. But it suffers from what specialized languages usually suffer from, namely, that the designers did not anticipate all the things that they would want to do. I'm always frustrated in DYNAMO when I want to put a function in my model that was not provided for in DYNAMO.

Just so that I don't point a finger at somebody else's language, one that I helped to design was a language for Project FIND, Dartmouth's administrative information system. FIND suffers from many more shortcomings than DYNAMO; there are all kinds of things we now want to do (some of which we have since added) that we simply didn't think of when we originally designed the language.

Therefore, one can be tempted to go to the opposite extreme and get higher level languages with which we can really do anything. Here I guess I must think of ALGOL as the prototype. The only shortcoming of a language like ALGOL is that nobody uses it — and I think there are good reasons why nobody uses it. Oh, I'm sure there are some exceptions to that statement, and perhaps all the exceptions are sitting in this particular audience. But still it's a probability-zero event that somebody will use it, and therefore as a probabilist I can still say that nobody does! The problem with ALGOL is that although it's a great dream, it is so horrendously general that it really is terribly difficult to use.

It has occurred to me in my thinking about higher level languages that what would really be nice is if users, and different kinds of users, would in effect be allowed to build their own languages. I'd like it to start not with machine language, because we should never go back to machine languages if we can avoid it, but with whatever one's favorite user-level language is. Mine happens to be BASIC and therefore I will use that for the sake of illustration, but it's not important to the points I'm going to make. It would be terribly nice if one provided a sophisticated software package, but in effect BASIC would always be there; then I would know I had a completely general-purpose language, yet I could make my own changes in BASIC and redefine things for my own purposes.

What kinds of things would you want to have? About the nicest additions to machine language have been what are called macros; macros are in effect a way to define your own instructions. You *can* do that in BASIC — that's what subprograms are for — but I think it would be very nice to have a conceptually simpler provision for them, where if you wanted to add a new instruction you could modify BASIC so that it took your favorite instruction and added it to the instruction set. Similarly the DEFine statement in BASIC, and similar statements in other languages, give you some freedom in adding functions of your own, but they're usually quite restrictive. For example, in BASIC you can add functions, but you can't add operations without some significant programming. I know many people have criticized BASIC, as compared with FORTRAN, because you can't give your pet names to the variables. It would be nice if you had your own building blocks with which to build a language; if you happen to like to give pet names to variables you should be able to introduce that option. But on a more fundamental level than this, suppose you were to think up a new kind of syntactic object, different from any that the authors of BASIC had thought of. It would be terribly nice if there were some means to introduce it, and if, from that point on, that language understood you when you used that kind of an object.

And that brings me to my second quote from a distinguished mathematician. It's one of my favorite quotes, and it's in two parts.

> "When *I* use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean — neither more nor less."
>
> "The question is," said Alice, "whether you *can* make words mean so many different things."
>
> "The question is," said Humpty Dumpty, "which is to be master — that's all."

This quotation seems appropriate to the question — not whether the computers should be master, for none of us could ever advocate that —

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but whether language designers should be masters over you or whether you should be master. The second part of the quote, which comes later in the passage, is also relevant; Humpty Dumpty has just used a single word to stand for something very complicated and long. Alice says, "'That's a great deal to make one word mean.'" And Humpty Dumpty replies, "'When I make a word do a lot of work like that . . . I always pay it extra.'"

We have computer users by the millions, and I believe that a great many of them would indeed be willing to "pay extra" if they could get words to mean what *they* wanted them to mean, and not what manufacturers of computers or designers of languages wanted them to mean.

In effect I'm advocating a do-it-yourself language, starting from a well-designed basic language. I've thought a little bit about how you could design a software package to achieve this, and my conclusions are that it is an extremely interesting challenge to design a language like that, and that I don't have such a design.

The reason I'm very much interested in that particular development is that many of us have made the remark at various times that one of the important things we have to achieve with computers is to make them able to learn from experience. One way to learn is through programming or through results of programming or sharing programs of other people. Once one has taught the computer to do one task one can use that in a more complex task. As one thinks of human learning, it seems to me an essential part of it is at some point to let the language grow. If human language had been static through history, we would have found it extremely difficult to make the amount of intellectual progress that mankind has indeed made. Therefore I think it will be a major breakthrough if one not only is allowed to program in a static language but if, at the same time, there is some provision made (and I have already admitted that at the moment I don't know how to do it, but I have some vague ideas) to allow the language to grow as our concepts grow.

The second part of my remarks about language deals with the subjects of error and ambiguity. Having talked with a great many elementary users of computers — and I happen to be very much interested in elementary users because the experts can always take care of themselves — I find that one of the major deterrents to wide use of computers is the incredible precision that is required in using a computer, precision that we do not require in communications between two human beings. A very minor misspelling, not to mention something that would correspond to misspeaking in a way that would be obvious, or something as small as leaving out a parenthesis, often causes significant and frustrating problems.

I know very well that there is no foolproof algorithm that can guess exactly what mistakes one has made. As a matter of fact, one can conclude that there cannot be such an algorithm. On the other hand, that does not mean that the computer couldn't make a reasonable guess as to what mistakes you have made, and perhaps suggest to you, as we would to another human being when he misspeaks, "Didn't you mean so-and-so?" That would be one small example of the kind of thing one could build into computer languages that would relieve frustrations.

In trying to think about the kind of tolerance for errors and ambiguity that one needs in computers that speak to millions of people, somewhere out there in their homes or offices, I can't resist some analogies to robots and the kinds of problems that we're going to face in that day (which seems to be receding rather than coming closer) when we will have robots in existence. There are some interesting parallels between the two problems. Make a mental leap and imagine for a moment that we now have household robots serving us. It seems to me that we, as the users of such a robot, would get extremely tired if every morning we had to tell the robot, "Now what I would like this morning is a small glass of orange juice, two soft-boiled eggs cooked five minutes, toast — not too dark — with a little bit of butter, and a cup of coffee — black, with two lumps of sugar," if that's what we had every morning of our life. We would certainly like to be able to modify the robot's language so it could understand a phrase like "Please make my usual breakfast."

This problem is very similar to the kind of thing that the average user would want to do from the home: not to have to repeat a great deal, but to be able to introduce his or her own terminology. Secondly, robots are nice ways of illustrating the problems of misspeaking. Somebody, not very long ago, asked me if I would please put the table on the ashtray. Yet I knew quite well the person didn't mean that, but wanted an ashtray put on the table. One has the horrible feeling that when that request is made of the first robot, the robot is going to pick up the table and smash it down on the ashtray, instead of asking if you didn't by chance mean the reverse. One worries even more about the fact that human instructions tend to be somewhat incomplete. There are an endless number of jokes about human beings giving instructions to computers and not giving quite the instructions they wanted, because we are so used to assuming in ordinary conversation a minimum amount of common sense on the part of the person we are talking with; we can't assume that with today's computers. One has a horrible feeling that when you tell that robot to please dump out the bath water, it will indeed dump the baby out with the bath water, because you didn't tell it to remove the baby first. Now these are amusing and perhaps not terribly important problems, but I want to suggest to you that they are quite fundamental, certainly at the stage of communicating with inanimate robots, but also at the level of communications with ordinary human beings who approach the terminal with excitement but also with fear, who are not going to be experts, who are not going to follow verbatim the instructions you have given them. Unless that terminal will accept some amount of error, misspeaking, mistyping and even ambiguity in what they say, we're not going to see tens of millions of people using computers. Therefore, for the two reasons I have mentioned — the lack of new kinds of user-designed higher level languages, and secondly, the lack of allowances for error and ambiguity — I'm convinced that we still need some major breakthroughs in the development of languages.

MEMORY AND RETRIEVAL

The second topic is memory and search. I don't think any of us doubt that very much larger memories are coming. The major problem I want to raise is this: when they come will we know how to use them? There are two different ways of using them, and there will be no problem with one way but, I suggest, very major problems with the other. That is, one can use an enormous memory for the same kind of storage we typically now have, let's say at Dartmouth College, except that instead of having the small amount of memory that is needed here for five thousand users one might have it for a million users. There I see very little difficulty indeed. Those large memories, however, make practical for the first time what lots of people are talking about — the storage of enormous amounts of information in very large and complex data bases. There I do ask whether we are ready to keep such data bases updated and usable, and whether we will ever be able to find anything in them. Much theory has come out in the last decade, some of it extremely interesting, on good ways of storing, updating and retrieving information. As I look at good algorithms and try to extrapolate them to data bases with perhaps a billion pieces of information in them, they strike me as incredibly expensive, and therefore they may not be practical. And the question I have asked myself is whether the problem is that we ask too much of these various algorithms.

Here I must make a parenthetical remark, because what I'm about to say concerning some of these storage and search procedures seems applicable to many other topics, with respect to the attitudes human beings have toward computers. Many people seem to find certain kinds of imperfections, which they live with happily or at least willingly outside of computer use, intolerable when it comes to computers. I feel that a degree of perfection is expected of computer usage that people would never expect otherwise. A good example of this is the concern about security of data bases in computers. I've been asked again and again here at Dartmouth College whether the various data bases we keep on our computer are really secure. The answer to that is no. On the other hand, I believe they are more secure than the usual storage for the same information, which is inside somebody's office and locked in an ordinary filing cabinet, both of which are easily opened by someone who really wants to do it. Not to mention that the commonest storage place for the same extremely sensitive data is the top of somebody's desk with the door unlocked. But somehow nobody seems to become paranoid if the Dean of the Faculty or the President happens to have this very sensitive data lying on his desk and he forgets to lock the door. On the other hand, if it is inside a computer and there is a one-in-a-million chance that somebody will get his hands on it, that somehow seems to be qualitatively worse.

The search for a foolproof or perfect algorithm must have limitations in the very nature of the demand. Look, for example, at the problem of designing strategies for certain kinds of games. I'm sure many of you are familiar with the famous theorem by John Von Neumann on games of perfect information. It says that for a game of chess there exists a perfect strategy for each player. Not only that, he described precisely how you would program a computer to find that perfect strategy. Unfortunately, his algorithm would probably take the rest of mankind's existence to complete; therefore it is not practical. This is why writing programs for good chess playing on the computer is an extremely challenging, difficult and fascinating task. But there comes out of it the recognition that although there exists in principle a perfect algorithm, and Von Neumann has told us how to find it, in practice we can't do that. Therefore we settle for less than perfection. But I don't think we have learned the lesson from that in enough different applications. For example, in the last few months I have twice heard from people who work on applications for businesses that in keeping enormous data bases one has to be terribly careful that not a single transaction should ever be lost. And even though they may do things like storing it twice, or also writing it out on tape, they worry about the problem of a crash occurring exactly in that millisecond between the time they've written it in memory and the time they dump it out on tape, so that they've irretrievably lost it. These very same businesses conduct these transactions by the U.S. Mail. I think that observation has its own lesson, and I won't elaborate on it.

Secondly, I feel that besides not asking for perfection here, this is an area where not enough attention has been paid to the role human beings should be playing and to why more of these algorithms aren't more significantly interactive. If I ask the computer to do a certain search and it looks hopeless to the computer, perhaps it should ask me how I could simplify the search for it. Perhaps the computer could be only 95% effective and it could ask me if that's acceptable to me. Perhaps I could specify the cost I'm willing to go to for a certain search or a certain algorithm, and the computer could give me as much service as I'm willing to pay for, which means designing quite different algorithms — say those that continually improve on what they have and perhaps might get you the largest payoff early and refinements later on, if it is worth your while doing it. Again, it seems to me that this is an area that needs some major new ideas before we tackle billions of pieces of information in a data base.

I want to close this part of my talk by making a comparison between human and computer memories. The appropriate quote from Lewis Carroll here is, "'—but there is one great advantage in it, that one's memory works both ways,' as the Queen remarked. 'I'm sure *mine* only works one way,' Alice remarked. 'I can't remember things before they happen.' And the Queen answered, 'It's a poor sort of memory that only works backwards.'" I could have chosen any number of other quotations to comment on how poor human memories are. However, I heard the talk by Von Neumann (many of you may be familiar with it, though it was twenty-five years ago) comparing the human brain with computers. I think, if anything, the evidence becomes more overwhelming each year, regarding how superior human memory is in extremely important ways to anything that computers can do. And the human memory seems to become more and more of a mystery the more we try to imitate it by computer parts.

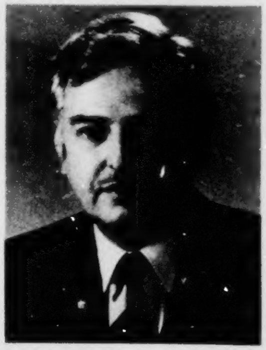
DIVISION OF LABOR BETWEEN PEOPLE AND COMPUTERS

My final thought — the one I warned you I find frustrating — is the division of labor between human beings and computers. In the early days the question was always, "Could this job be done by a computer instead of a human being?" Gradually it has become clear that whenever there is any doubt at all as to which is preferable, the best solution is a symbiotic relationship where man and the computer work together. And indeed there have been significant gains in this in the last decade. Interactive systems have become quite common. They have become much easier to use, with better languages and with things like intelligent terminals, and they really are qualitatively much easier to work with. In addition, we have found better ways of communication. Language improvement comes in here again. But also the display devices now available, particularly the major breakthroughs in computer graphics, have helped enormously in having the computer summarize very complex information for human beings.

But these have marked progress in the tools or in the needs for the division of labor. They have not been philosophical breakthroughs. I still have a "gut" feeling that we do not know what would be an ideal or nearly ideal division between computers and human beings. When I try to think of a good way of telling you what worries me, again I find I'm thinking ten years ahead to very large systems, enormous memories, billion-step calculations. And here instead of a Lewis Carroll quote I am reminded of one of my favorite stories concerning another very famous mathematician, Bertrand Russell. According to the anecdote, he attended an after-dinner seminar where a well-known philosopher was speaking, and he fell asleep very soon after the other speaker began and awoke just shortly before the end of the seminar. It was a small enough group (and Bertrand Russell would be noticeable in any group) that the speaker was quite irate and immediately turned to him and asked him what he thought of the lecture. It was clear to Russell that the speaker had noticed he had fallen asleep, and he replied frankly that after the large meal and being in an over-heated room he had dozed off. On the other hand, he had heard the speaker's introductory remarks, and he did hear the speaker's conclusions. And knowing how logical the speaker was, he was absolutely sure that everything in between followed strictly logically; and therefore he, Bertrand Russell, could say that he agreed with everything that the speaker had said.

This particular speaker was notable for the fact that he liked to be flattered, and Russell got away with that statement. But we find ourselves in just that sort of situation in a great many large uses of computers, in that we are daring to pose the problem at the beginning and to give the computer the data and the requests. And a billion steps later — now it's a million steps but it will be a billion steps later — we see what comes out of the other end. And we can even assume that everything that the computer did in between was highly logical, because it has no choice in that. But that does not mean that everything it did in between had any resemblance at all to what we hoped it would do. I do not have enough confidence in our ability to think a billion steps ahead and to anticipate absolutely every kind of trouble that the computer can get into. And the larger the applications become, the more worried I am about turning the computer loose, so to speak, and then seeing what comes out of it.

It is fundamental to the symbiotic relation between computers and human beings that our respective talents are quite different and complementary. The computer provides speed, accuracy, phenomenal memory, and many other things. Human beings provide intuition, judgment and creativity. But I worry that as computer science develops, we will take less and less advantage of the talents of human beings. It is terribly important to remember just how different we are. Of course, the more different two species are, the more challenging and the more difficult the symbiotic relations become, because one has to figure out the best way of using the talents of each. And the solution we come up with for that particular problem is, in the last analysis, going to determine the nature and the value of the symbiosis.



Dr. Kemeny has been President of Dartmouth College since 1970 and is a Fellow of the American Academy of Arts and Sciences. Prior to assuming the presidency, Dr. Kemeny had been a Professor of Mathematics at Dartmouth since 1953. During World War II he served in the U.S. Army as assistant in the theoretical division of the Los Alamos Project and then as a research assistant to Dr. Albert Einstein at the Institute for Advanced Study. Dr. Kemeny has been a consultant at the Rand Corporation, Chairman of the U.S. Commission in Mathematics Instruction, member of the National Research Council, and Vice-Chairman of the N.S.F. Advisory Committee on Computing. He is a trustee of the Carnegie Foundation for the Advancement of Teaching and director of the Council for Financial Aid to Education. He has written and co-written numerous books and articles, including Man and the Computer *and* Basic Programming. *He earned both his B.A. and his Ph.D. from Princeton University.*

ABSTRACT

Electronic funds transfer holds many promises, but even among informed observers, the jury is still out. The technology is here; the markets are latent but substantial; the economies, at least for the moment, appear marginal; and the social implications, though largely unknown, seem ominous to some, beneficial to others.

Electronic Funds Transfer: Progress and Issues

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Electronic Funds Transfer (EFT) seems a particularly appropriate topic for this symposium on "Man and the Computer." In a paper titled "Value Choices in EFT Policy"[1] that was prepared for the Office of Telecommunications Policy, Professor James Rule of SUNY, Stony Brook, observed that "electronic funds transfer is as authentic an instance as one could wish of technical innovation with potential for far-reaching long-term social effects."

Professor Rule's paper is outstanding for its thoughtful and comprehensive analysis of the potential — both good and not-so-good — of EFT. He notes that what makes the study of technological changes fascinating, and what often makes such changes seem to be endowed with wills of their own, is that the long-term effects of new technologies are often difficult to anticipate. That is what we have here: a subject which is essentially technology-based, one which is going to affect the population at large, and one for which the implications are unclear at best. Although I'm not as much a doomsayer on the implications of EFT as some, I agree that caution is advisable.

I'd like first to present a brief overview of the current status of EFT, including introducing you to the key players in the EFT arena. Then I'll focus on some specific aspects of that status under the general headings of technology, markets, economics, and legislation. Finally, I'll mention a few of the more complex issues currently under discussion.

I should declare at the outset that much of what I will say is from the perspective of someone familiar with banks and bank credit cards; I am less familiar with other important aspects of this problem, such as retailing. I'll try to keep perspective and bias separated.

Everyone has heard about EFT, yet it's not an easy subject to define neatly. We now have a payment system in the U.S. — one overwhelmingly based on the clearance of checks. Approximately 90% of our households have checking accounts, and 30 billion transactions per year are settled by check — one hundred million per day. But EFT obviously deals with more complex elements than the clearing of checks. To cut through that complexity, I find it helpful to categorize these elements under several headings.

In the first category are preauthorization techniques whereby, for example, you agree with your bank (or perhaps with a thrift institution) that, without any further action by you, funds will be transferred every month from your account (either checking or savings) to a creditor, such as an insurance company, public utility, or the holder of your home mortgage. Similarly, your bank account can be credited by the direct deposit of a paycheck, social security check, or dividend. In both cases, the process is entirely "automatic" once you have initially authorized it.

The second category is automated banking whereby you use an automated teller or similar device to deposit or withdraw funds, to transfer them between your checking and savings accounts, or from one of your accounts to that of a third party. Devices of this sort are being installed in a number of off-bank-premises such as supermarkets, airline terminals, student unions, and apartment complexes.

In the third category are point-of-sale devices whereby purchases are either charged to your checking account directly (using a debit card) or to your credit account (using a credit card); point-of-sale devices appear in retail outlets, restaurants, and hotels. (It is interesting to note that Dartmouth President John Kemeny foresaw the debit card in his book *Man and the Computer*[2] several years before the banks took the idea seriously.) Debit cards, unlike credit cards, are used to transfer funds directly from your account to the account of a merchant. Instead of drawing on your credit at the bank, you use funds that you previously deposited.

The fourth category combines the features of several of the others to allow, for example, the use of a touch-tone telephone to pay bills from your home. As of last month, one system of this type was operational at ten banks in Minneapolis, Pittsburgh, Des Moines, and Seattle; forty more banks were said to be under contract. In this particular case, the consumer pays ten cents per transaction. A voice response assures him that the transaction was entered properly. Unfortunately, he has to make 36 key strokes for every transaction. Given the human propensity for error, it's understandable that the voice-response feature is necessary.

These systems, services, and devices are not entirely new; some of them have been around for quite a while. What's new is that they are coming at us in a rush, and that they're being offered by a wide variety of organizations, some of which have not previously offered financial services to consumers.

Who are the players in the EFT arena? First, there are banks, groups of banks, and joint ventures that include banks. Of particular interest are the Automated Clearing Houses (ACH's) which have been established for the purpose of exchanging paperless documents (either electronic or magnetic tapes), and of handling debits and credits between buyer and seller (or between banks). Approximately thirty ACH's are now in operation around the country. Typically, there are five key participants in an ACH-type transaction: the customer (or employee), the merchant (or employer), an originating "bank" (which need not be a commercial bank), the clearing-house itself, and a receiving "bank". The ACH's make it possible for you to transfer money from your account to your insurance company to pay premiums each month (the preauthorized transfer described above).

Another class of players is made up of thrift institutions: mutual savings banks and savings and loan associations. Thrift institutions have been particularly innovative and aggressive in certain states and, in the process, have alarmed the commercial banking community (which in most cases operates under more restrictive legislation).

Still other players include credit unions, credit card service organizations (such as Interbank Master Charge, National BankAmericard, American Express, and Diners' Club), and a number of commercial profit-making enterprises (such as TRW and National Data Corporation).

Retailers (such as Sears Roebuck, J. C. Penney, and Montgomery Ward), although maintaining a relatively low profile thus far, in the sense that they have not stepped outside their own domain, promise to be very important players in the EFT arena. Sears, for example, has larger amounts of credit outstanding (dollars owed by credit customers) than either BankAmericard or Master Charge.

Finally, the federal government is a player through its numerous agencies that are (or would like to be) directly involved. These agencies include the Federal Reserve Board, Federal Home Loan Bank Board, and Federal Deposit Insurance Corporation, to name only a few.

A body with the potential for substantial influence on the future of EFT is the National Commission on Electronic Fund Transfers. This commission was created in October 1974 to examine the policy ramifications of emerging payment mechanisms in both the public and private sectors, and to recommend appropriate administrative action and legislation. It was given a two-million dollar budget and two years to report. Because of a one-year delay in getting started, however, the Commission is now due to report in October 1977. Its twenty-six members include fourteen designated high-level federal officials (or their designees), e.g., the Chairman of the Board of Governors of the Federal Reserve and the Controller of the Currency; seven representatives of the banking, thrift, and credit card industries; and five individuals from private life. Unfortunately, no knowledgeable member of the computer or data processing community has been named to the Commission, despite the efforts of the American Federation of Information Processing Societies, the Association of Data Processing Service Organizations, and others.

The Commission has formed a Users' Committee (which will examine any consumer, industrial, or government agency that makes use of EFT services), a Producers' Committee (which will examine any financial institution that presently offers or could potentially offer EFT services), a Regulators' Committee (which will examine any federal, state or international body that regulates any aspect of the electronic payments process, including communications), and an EFT Suppliers' Committee (which will examine any organization that supplies services or equipment to EFT producers). The Commission's committee structure testifies to the complexity of the issues it faces.

On the sidelines (but very vocal) are a gaggle of trade associations and consumer groups. Some which have appeared at various hearings recently on EFT include: Credit Union National Association, National Consumer Finance Association, National Association of Food Chains, American Bankers' Association, Independent Bankers' Association of America, National Association of Mutual Savings Banks, National Association of Federal Credit Unions, U.S. League of Savings Associations, Consumer Federation of America, American Civil Liberties Union, National Public Interest Research Group, Consumers' Union, Supermarket Institute, and National Credit Union Association. As Professor Rule wrote in his paper, "Specific categories of people pursuing their own distinctive ends . . . ."

Unfortunately, battle lines are being drawn in an atmosphere best described as chaotic.

Technology is really not the big issue in EFT; if anything, we have more than we know what to do with. I cringed when I saw an advertisement in a trade paper the other day which offered "a communications-oriented electronic funds transfer system kit." A kit! — with 20 terminals, modems, a plastic card reader, a PIN (personal identification number) pad, and a communications concentrator/controller configured for two phone lines and connection to a host central processor. Price: $30,000; delivery: early next year. I don't mean to belittle that accomplishment, but to me it suggests a somewhat simplistic view of the problems that would-be suppliers of funds transfer services will face.

As I said, the technology for EFT is in oversupply; but *standards* for technology are a major problem. Systems are cropping up in helter-skelter fashion around the country, primarily at local and regional levels. But if these systems are to survive, they must someday provide for the interchange of transactions nationally, even internationally. That, of course, requires standardization of message content, formats, and protocols. On a related matter, there has been some progress in developing standards for plastic cards, but not as much as you might think. For example, an international standard has been drafted for the third magnetic track on the back of the card — a track originally proposed by the thrift industry. But commercial banks not only don't use that track, they don't even have a third track on their cards, and their card readers weren't designed to read it. Furthermore, oil company cards don't have *any* stripe on them; the airlines plan to use stripe technology, but theirs is not compatible with that of the commercial banks either. Retailers, too, present a problem: they don't use magnetic stripe technology at all; instead, their credit cards' merchandise tags rely on a variety of optical character recognition codes and techniques. As you can see, we're a long way from any rational set of standards for EFT.

Security is another technology-related issue that is up for grabs, and no one is quite sure how to handle the myriad operating details encountered in practical applications even when techniques are known; for example, the length, format and content of PIN numbers and the methodology for encryption/decryption of transaction data.

Commercial banks are scrapping with one another in an effort either to establish a proprietary position in the market or to recapture market share from their competitors down the street. At the same time, thrift institutions would like to expand their service offerings to attract the same customers and their deposits. Yet consumer reaction to EFT has been generally lukewarm and cautious.

Professor Rule comments on the "beguiling convenience" of consumer-oriented EFT systems and predicts that widespread public acceptance would be extremely likely. Yet others aren't so sure: Professor Leonard L. Berry of Georgia State University argues that the consumer perceives a relatively weak advantage to some EFT offerings and concludes that acceptance is going to be slow[3].

Consumers are understandably apprehensive about the possibility of having to pay for services which were free in the past. They are concerned about potential loss of control over their personal financial transactions. They're becoming concerned about the threat of surveillance. And they've been decidedly cool to certain new EFT services that are perceived to impinge on their personal lives. For example, automatic payroll deposits allegedly haven't been universally popular because not every wage earner wants his or her spouse to know how much he or she earns. The more cynical observers point out that if all paychecks were deposited directly to individual bank accounts, receipts in local bars would fall off substantially on payday.

In spite of the fact that consumers haven't yet shown overwhelming enthusiasm for EFT services, growth statistics are nonetheless impressive. According to Arthur D. Little, the total value of installed EFT equipment will increase from approximately five billion dollars this year to thirteen billion in the next ten years. The number of terminals installed in supermarkets at the end of September 1976 was estimated by International Data Corporation (IDC) to be 36 thousand; that number is expected to increase by 64% in the next nine months. IDC projects 400 thousand terminals by December 1980, a tenfold increase in four years.

To me, these statistics indicate that markets are in fact developing, and consumers are beginning to accept certain EFT services as useful. But it's clear that consumers are not about to be stampeded into accepting EFT until their misgivings are allayed.

ECONOMICS

There is no question that funds transfer services will have a fundamental impact on the structure of the financial services industry as we know it today. The new competitors — some of them well-financed, aggressive and agile — are likely to raise havoc among the traditional suppliers, particularly among those commercial banks which view themselves as competing only with other banks.

As noted above, substantial capital is being invested in EFT hardware; the accompanying software will require a large investment, as well. But capital-intensive businesses have high fixed costs, and high transaction volume levels must be reached in order to break even. The tougher competitors will understand that instinctively and they'll be willing to cut prices in order to build volume. But few banks are accustomed to competing in an arena where one cuts prices; that type of competition will be an entirely new — and uncomfortable — mode for many of them.

The competitive pressures will be aggravated by the fact that it is very difficult to project capacity requirements when products are new and transaction volumes can only be guessed at. Inevitably, a few unlucky suppliers will build systems that prove to be either very much over — or very much under — capacity. Consequently, there will be considerable variations in operating costs leading to unstable pricing and throat-cutting.

The *American Banker* recently published (and labeled as "Required Reading") a speech by James B. Farley of Booz, Allen & Hamilton[4]. Farley challenged bankers to answer two questions: (1) "How do you make money on transactions?" and (2) "Are you willing to restructure your organizations, so that all of the pieces of retail — that is, marketing, systems, facilities, product development, pricing, etc. — are under one authority?" Farley suggests that few banks know how to make money on transactions, and that marketing efforts are hopelessly fragmented for most of them. If he is correct (and I believe he is), stand by for some very creative accounting.

LEGISLATION

Professor Rule points out that a new means of producing something which people want — whether an invention, a technique of mass persuasion, or a legal mechanism — is bound to become an object of competition among interests that would like to monopolize it. So it is with EFT, where the environment is very tense — and the outlook very murky — from a legal and regulatory point of view. There already are numerous banking laws and regulations on the books, some of the more important ones forty years old. Among other things, these laws were intended to define the role of, and relationships between, banks chartered under state and federal banking statutes. Still more legislation is being drafted each day, most of it controversial — and much of it conflicting at state levels. Donald I. Baker, a noted antitrust lawyer, warns that if EFT development is loaded down with legal restrictions to protect existing institutional interests, and with expensive obligations to serve the dreams of social engineers, it is likely to lose whatever cost-effective advantages it now has[5].

In a recent issue of one of the newsletter services that follows EFT developments, the following phrases appeared over a span of only four pages: "legal hassles," "legal ambivalence," "legal confusion," "could be declared illegal at the drop of an injunction," "but for the law," "legal strangle-holds," "legal barriers," "legal tangle," "legal cloud," "ubiquitous legal hassle," and "basically hostile legal environment." One might conclude that legal issues are a hot topic in the EFT community.

A basic question is whether legislation should be permissive or protective. And if permissive, permissive of what? If protective, protective of/from what? Given the number of onlookers and spokesmen with diametrically-opposed points of view — the commercial banks, the thrift institutions, the civil libertarians, the credit unions, the consumer advocates, the bureaucrats, the retailers, and the supermarketeers — it's not surprising that the air is filled with controversy. Mr. Farley suggests that these "energies spent on resisting . . . change could be better spent on developing a healthy evolution toward some profitable solutions to obvious but highly complex problems."

Legal issues seem to fall under one of four headings:

- Those related to branch banking (affecting only commercial banks at the moment)
- Those that deal with privacy considerations
- Those dealing with such matters as the responsibilities of the parties in a variety of day-to-day commercial transactions (for example, cashing a check); these are closely related to ambiguities that arise in applying the Uniform Commercial Code to EFT transactions
- Those issues (related to antitrust and fair-trade laws) dealing with who must share what EFT systems and equipment and the degree to which a competitive environment will be mandated

Certain aspects of the law in each of these four areas are now being appealed in courts at all levels; others are awaiting review by the United States Supreme Court.

The National EFT Commission has recently adopted several resolutions which give us some insight into its thinking. It is impossible, of course, to predict what legislation will eventually evolve from the Commission's deliberations since it can only recommend legislation, not enact it. Or, as the old farmer put it, "Chickens don't buy chicken feed; farmers do." The substance of these resolutions is as follows: the Regulators' Committee has resolved that electronic terminals should *not* be considered branches (a thorny issue) and that "the conditions under which they may be established should *not* be determined by laws, state or federal, which govern . . . branches." This would have the effect of encouraging much wider distribution of EFT terminals — to supermarkets, shopping centers, etc. — than has been legal under existing law in certain states.

The Providers' Committee has resolved that every deposit institution should have equal access to automated clearing-houses (the issue has been whether the thrift institutions should have the same access rights as do commercial banks). It strongly supported a competitive private enterprise in the development of point-of-sale switching, adding that a subsidized operational role on the part of either government or ACH's "is not necessary and could be detrimental."

The Users' Committee has resolved its support for "the widespread use of electronic payments systems for the purpose of dispensing cash and the effecting of payments for goods and services"; it has expressed its concern regarding the impact of EFT on the consumer in the general areas of privacy, security, and consumer credit.

ISSUES

I'll summarize by mentioning several key EFT issues without attempting to present any arguments, pro or con:

- What role should the federal government play in operating EFT systems? In regulating them?
- To what extent should the shared use of funds transfer hardware, software, and communications networks among providers of EFT services be mandated?
- Who is to be responsible for the safekeeping and security of funds transfer data? The organization that maintains the account, the organization operating the switch, or the party who initiated the transaction?

- How can unauthorized access be detected? How can intruding parties be identified?
- Who can authorize legitimate access to EFT data — the courts? The IRS? Welfare officials?
- What obligations should be enforceable through EFT? Should it be possible for a governmental agency to collect taxes by debiting personal checking accounts without prior authorization by the taxpayer? Should the courts have similar powers relative to alimony or child support payments?
- Who should be held responsible for faulty goods, stolen cards, and disputed transactions?
- What EFT policy will produce a socially desirable and politically acceptable compromise between convenience, efficiency, privacy, and personal autonomy?

The last issue is, of course, the toughest of them all because it involves a choice of values. It seems clear that compromises will be necessary between policies that are socially desirable and politically acceptable and those that are economically sound, as well. Some observers question whether EFT in any form is socially desirable because it necessarily involves the collection and use of personal data.

Personally, I look forward to the availability of funds transfer services. I'd like to be able to preauthorize payments to certain creditors for such items as insurance premiums, mortgage payments, and utility bills. I'd like to be able to pay other bills using a touch-tone telephone. I'd like to keep funds in an interest-bearing account until I need them, transferring them to my creditors only when I'm ready to do so. I don't feel particularly threatened by EFT since my spending habits and whereabouts are already well documented at the bank that services my checking account and my credit card account, and I seriously doubt that the bank could afford — or is motivated — to keep a long-term dossier on me. I am leery, however, of the enormous power of governmental bureaucracies because, unlike my free choice of a bank or bank credit card, I can't elect not to do business with them. And they are for all practical purposes immune to the kind of economic pressures that I feel protect me in dealing with my bank, or with any other profit-making enterprise. Nonetheless, I am enthusiastic about EFT services, provided only that I have the option to use them or not use them as I see fit. That option is the key to my peace of mind.

One final note. President Kemeny made a prediction in his book *Man and the Computer* with which I must respectfully disagree. He said, "I am convinced that for items exceeding one dollar in price cash transactions will totally disappear." Not likely, sir, unless we abolish the IRS in the meantime!

REFERENCES

1. Rule, James B. *Value Choices in Electronic Funds Transfer Policy.* Washington,D.C.: Office of Telecommunications Policy, Executive Office of the President, October 22, 1975.
2. Kemeny, John G. *Man and the Computer*. New York: Charles Scribner's Sons, 1972.
3. Berry, Leonard L. "Psychological Reasons Hindering EFT Acceptance." *Computerworld*, September 13, 1976.
4. Farley, James B. "Electronic Funds Transfer Can Compound Retail Banking Problems." *The American Banker*, October 18, 1976.
5. Baker, Donald I. *The Magazine of Bank Administration*, December 1975.

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ABSTRACT

A review of nine computer models used to study national policies for economic development indicates that the strengths of computer modeling are not being realized, and the weaknesses are far too evident.

The Electronic Oracle: Computer Models in Public Policy

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As far back as we are able to look in history there have been social policy makers — people who have taken upon themselves the privilege, or the burden, of making decisions that affect a large part of society. Not far away from each of these policy makers has always been another group of people whom today we might call "futurists" — people who tell policy makers what the future will be like, and what the results of various decisions might be. The Greeks had their Oracle at Delphi. Every medieval ruler kept a stable of astrologers. Gypsies with crystal balls have always been able to find employment.

The other day I found a delightful page in my dictionary that listed a number of the ingenious methods that people have used to predict the future. These are just a few words from a very long list: bibliomancy, divination by the Bible; hieromancy, telling the future by looking at the entrails of sacrificial animals; geomancy, looking at dots made at random on paper; and one that sounds very messy but kind of fun — ceromancy, dropping melted wax into water.

We like to think that we now live in an age of reason and that we can probably devise better methods than these for looking at the future and advising social policy makers. The policy makers are still very much with us, and they still feel a pressing need to know about the future in order to make their decisions. But if you look carefully now at the modern and most progressive social policy makers, you find not astrologers and not oracles, but computer modelers around them. Being a computer modeler myself, I tend to think that is a good trend. Computer models certainly should offer some great advantages over hieromancy and ceromancy, and also over the other forms of prophecy available to us at the moment.

COMPUTER MODELS VS. "MENTAL MODELS"

The primary source of wisdom about the future is still the same as in the days of the Delphic oracle — it is the "mental model." A mental model is simply the accumulated wisdom of one person — a set of generalizations stored in each of our heads about what the world is like now, and what it may be like in the future if we do X rather than Y.

Computer models could at least theoretically have some significant advantage over mental models. For example, the simple process of getting something into the computer requires a tremendous amount of organization, rigorous thought, and precise refinement of one's assumptions. Just the process of putting down what one thinks about the world in a systematic way is often very useful. It is a hard process, just because mental models usually prove, upon close examination, to be fuzzy, internally inconsistent, and incomplete. Computer models have to be better than that; otherwise the computer rejects them, usually with some rude comment such as VARIABLE X UNDEFINED, or ILLEGAL INSTRUCTION IN LINE 20.

Another potential advantage of computer models is that they are explicit. They are written down, so a critic can look at the assumptions and expose, alter, and correct them. That is simply not possible with mental models, which are shifting, ambiguous, and essentially inaccessible to criticism.

A third possible advantage of computer models is that they can be very much more comprehensive and complete than mental models. They can accommodate more information than one single mind can contain, process more information, and keep track of more data at one time. They can essentially combine the mental models of many people, and therefore, in a two-heads-are-better-than-one way, come up with greater wisdom or better predictions of the future.

Computer models can also take any set of assumptions and derive from those assumptions an error-free conclusion. You can say what you like about the assumptions, but the computer will at least find the logical result of assuming all of those things at the same time. This is one job that mental models do not do well at all. You have certainly been involved at some time in an argument where both sides have agreed entirely on a set of assumptions and still disagreed about what conclusions should be drawn from those assumptions. Presumably computers could help out in situations like these.

A final advantage is that computer models can be easily altered and tested and run with different assumptions, policies, scenarios, or guesses about the future. They can be changed much more easily than the real system can be changed and also more easily than our mental models can be changed. Therefore they permit relatively easy exploration of system behavior under conditions that could never be explored any other way.

These are all, to me, impressive reasons for trying to use computer models to advise in the formulation of policy. But are the models that are available now actually delivering all these advantages? In fact, computer models are not often used, and when they are tried, they are not often judged useful. An increasing number of critical books and studies about computer models for social policy making are appearing, many of them suggesting that we give up the idea of modeling entirely, since the record so far has been so bad. NSF-RANN, one of the major federal funders of application-oriented computer models, have recently put a moratorium on further funding until someone convinces them that the roughly 100 million dollars they've already spent on socially-oriented computer models have produced anything worthwhile.

REVIEW OF NINE MODELS OF SOCIAL SYSTEMS

I was asked two years ago to conduct a study of computer modeling of social systems, to review the history of some actual models designed as inputs to social policy and to ask what in fact they had contributed to social policy. I'd like to tell you today some of the things my assistant, Jenny Robinson, and I found out in the course of this study.

We began with a sample of nine models. These nine were chosen because they all covered one particular general policy area; therefore they could be compared to each other to some extent. That general policy area was the interaction of population, resources, and economic development on the national level; that is, we focused on broad-scale models for national policy makers. Another criterion for selection was that they all be completed and therefore documented and accessible to us. It turned out that very many models were not useful for our survey because they had never reached the point of documentation. All of the models that we chose were also recommended to us either by the policy community or by the modeling community; they were all essentially well thought of and well known. We tried to pick the best examples that we could find.

The models cover a variety of different countries, including Korea, Egypt, the United States, and Mexico. The modelers used every kind of analytical technique: systems simulation, input/output analysis, econometrics, linear programming. The models were made either for or by organizations such as the World Bank, the United States Agency for International Development, various branches of the United Nations, and the Environmental Protection Agency. In some cases they were made by in-house modelers, and in some cases by university or think-tank contractors. I believe that these models are fairly characteristic or slightly better than the general run of models. I should also point out that none of the models was made by anybody at Dartmouth College.

I'd like, first of all, to put forward a few general observations on the models without going into any details or even telling you their names. And then I would like to conclude with a few suggestions as to how things might be made better, because it will be apparent to you that my conclusions are rather negative, even although my original bias was positive. I emerged from the study horrified at the state of the art of my profession. I'm still convinced that computer models can be useful and can exhibit all the advantages I have already outlined. On the other hand, as you will see, I have not yet seen many good examples to illustrate that conviction. I should also point out that my remarks are applicable only to social policy-oriented models. There are many other uses of the computer that will be discussed here over the next three days, and my comments don't apply to most of those uses.

Let's go back over that list of advantages I just gave you and see the extent to which any of those advantages is actually realized by the sample of nine models.

INTERNAL CONSISTENCY, RIGOR, AND PRECISION

The first point I made was that *computer models are rigorous and precise*, and that it is a useful process to state one's assumptions clearly and to make them mutually consistent. Of course all nine models, in order to get running on the computer, had to be rigorous, consistent, and precise. In some cases the method used forces a certain amount of consistency. For example, any input/output model requires that anything someone sells has to be bought by someone else. It also doesn't allow you to make more automobiles unless you also make more steel, and then it requires you to make more coal for the steel, and then more coal-mining equipment, and so on. The very nature of that kind of model forces a degree of internal consistency impossible to maintain in one's head.

Another good example is a model on agricultural development in Korea. While the modelers were looking for data, before their model was even begun, they discovered that the figures on Korean agricultural production looked strange. In fact the field production figures agreed exactly with the five-year plans of the Korean government. Looking a little closer, the modelers discovered that the same agency that made the plans also collected and reported the data. As a result of that finding, the whole data-collection process in the Korean government was changed, so that agencies that report actual events are no longer the same ones that make the plans. That achievement did not directly follow from a computer model, but it wouldn't have been done if a modeling process hadn't been going on.

Well, that's the good side. The bad side of the "rigorousness" characteristic is exhibited by one of the nine models we looked at, which is extremely rigorous about what I could only call a dream system. It is very precise, internally consistent, extremely complicated, and has almost nothing to do with the real world. No data are used, no historical comparisons are given. It is a beautiful system, but it can provide no lessons about the current world; its only possible use would be to design a new one, but that was *not* the task of the policy agency that sponsored the model.

Six of the nine models are very rigorous about processes that are easy to represent. They transfer all nine-year-olds into the ten-year-olds category in the following year. They see to it that the acres of agricultural land cultivated do not exceed the land area of the country. These are useful accounting functions, but these same six models push the really critical things, the things one really wants to know about, out to the boundary of the model. All the interesting things must be predicted outside of the model. For example, here are some variables that must be predicted *before* some of these models can run: population growth rates, GNP growth rates, technological change, market prices, investment rates. In the majority of the models that we've looked at, mental models must provide that kind of information; then the computer does some very elaborate, rigorous, precise transformations and tells you how many ten-year-olds there will be.

To summarize this point, many of the models tend to be rigorous and precise about the wrong things, or are very rigorous and precise structures built on a base that is nothing more than a mental model. It might have been more direct and more honest to just make a mental-model forecast to begin with.

EXPLICITNESS AND ACCESSIBILITY TO CRITICISM

The second possible advantage of computer models is that *they are explicit and therefore open to criticism* in a way that a policy made within one single head can never be. The best example of that advantage in our sample is one very simple economic-demographic model that was made in order to convince nonindustrialized countries to spend money on family planning. It was really a propaganda model, made to teach a lesson that the modelers already knew before they began modeling. The model is very clear, very explicit, and the assumptions are so obvious and outrageous that at least two other modeling groups took it upon themselves to make a countermodel to correct the ridiculous simplicities of the first model. In fact all three of these models are included in our sample. I consider the whole sequence of three a very good example of modelers building on each other's work, keeping their assumptions explicit and clear so others can react to them and change them.

Out of the sample of nine models, I would say three really meet the criterion of being accessible to criticism. The other six were extremely difficult for us as professional modelers to penetrate. I would guess that two of them are total mysteries even to the makers of the models. One of the models, an incredibly complex one, simply cannot be reproduced, even by the people who made it. The conditions that led to the published results are lost; the equations are not available any more.

Another model requires an input of 80,000 numbers before it can be run. It simulates an agricultural economy where farmers can choose among 2340 ways to use their land, depending on the prices from 16 produce markets and about 10 input factor markets. The markets are balanced by the simultaneous solution of 3500 equations. The modelers may actually understand how this model works and where it does and does not resemble the real world, but they have never been able to explain it in any language I can understand.

With three exceptions, the documentation of these models is abysmal. Remember that every one was selected because it was a documented model — the majority of policy models are never described in written form at all. But the documentation, where it does exist, is unorganized and full of jargon. In most cases the equations are not given, although usually we could track them down by going directly to the modelers themselves. The data sources are very rarely identified. Worst of all, the really important assumptions in any computer model are not those that are embedded in the equations; they are those that are implicit in framing the question, in choosing the methodology, in deciding what to leave out of the model. In none of the cases was any of that part of the modeling process explained. In fact most modelers don't seem to be aware that there are assumptions implicit in that part of the modeling process. In other words, the majority of the models we looked at are not accessible to criticism, except perhaps from a limited and specially-trained group of people. If any policy maker actually paid attention to these models, he must have done so on faith, not on rational understanding. We have not really come very far from the Delphic oracle.

COMPREHENSIVENESS AND COMPLETENESS

I have said that *computer models can be more comprehensive and more complete than mental models*. Again there are some good examples and some bad ones. In our sample there are some interesting crossings of interdisciplinary lines. There are models that contain economics and geology and ecology and demography all together. In some cases the model has served as a communication vehicle, allowing interdisciplinary groups to talk to each other through the common language of mathematics.

Three of the models, for example, close a very important cross-disciplinary feedback loop from the economy to the population, a connection that is very hard, I have found, for people to keep straight in their minds. These three models indicate not only that the population affects the economy in various ways, but also that the economy affects the growth of the population. Inability to keep both of these connections in mind has broken up many a meeting on the problems of economic development, and was the major item of contention at the recent World Population Conference. The three models that contain both connections illustrate that in fact both sides of the argument are right, and that is a step toward a greater understanding of how social systems, especially developing economies, really work. Unfortunately, six of the models contain only one of the necessary links.

In most of the models, the theories underlying a great deal of mathematical elaboration are in fact surprisingly simple, and hardly comprehensive. In virtually every model markets clear instantly, people make optimal decisions on the basis of perfect information, and economies make wonderful products using only capital and labor, no energy or resources. These are approximations left over from the days when calculations were made with paper and pencil. Even our mental models are more complex than that.

We know an immense amount of qualitative, but nevertheless accurate, information about how people make decisions and about the constraints, goals, motivations, and expectations that influence the workings of an economy. Virtually none of that qualitative, mental-model information is included in these formal mathematical models. I would say only two of the models in our survey make any attempt to represent goals or expectations or the motivations behind human decisions. Very few of the models represent any social or political factors at all. Only three represent any resource or ecological constraints on the economic system. These are biased omissions. These models are incredibly complete about some things, and yet strangely naive or even silent about other things that we know, in our mental models, are important parts of social systems.

The reasons for these omissions are fairly clear. Although there is plenty of anecdotal information about motivations, for example, there are no data of the sort that computer modelers like. Our observations in these areas are so qualitative and mushy that our methodological biases tell us to leave them out, even though leaving them out may be the one undoubtedly wrong way of representing them. Also, it is mathematically very difficult sometimes to include a number of things that we know are really true of social systems. For example, there is often a delay between initiation of an action and its actual effect. Or the relationship between A and B may be nonlinear instead of linear. We recognize this nonlinearity, but mathematically it is so much easier to make it linear. In fact eight of the nine models essentially say that social systems are linear, they are continuous, and they instantaneously adjust themselves to perfect information about what's happening in every other part of the system. In short, computer models *could be* more comprehensive than mental models, but they usually are not. They are totally blind to some things our mental models easily take into account. The blindness arises primarily from mathematical convenience or methodological bias. Unless these biases are overcome, computer models are unlikely to give a very accurate picture of real social systems.

ABILITY TO DRAW ERROR-FREE CONCLUSIONS

The fourth possible advantage of computer models is that they can *draw error-free conclusions from their assumptions*. Though, as I said, six of the models are really inaccessible to me and so I have no way of checking that, the other three do seem to be mathematically correct. I worry about the other six. I know myself, as a modeler, how easy it is to mistakenly invert a ratio, or to get a decimal point in the wrong place, or to make a typing mistake. I simply don't know how a model with fifty thousand equations can be checked rigorously for such errors. I suspect that they probably haven't been. I do have some good examples of rigorous checking to tell you about, however, as well as a few bad ones.

In three cases the output of the model surprised the modelers. They thought they knew how the system worked and what policy should be selected, and, like virtually all modelers, they constructed their models to produce a certain result. But the model told them exactly the opposite.

In one case the model results showed that the economy of a poor nation would be better off if all U.S. aid measures would be stopped. In another a system that had been constructed to be adaptive to resource shortages turned out not to be. In the third model aid measures designed to help the rural sector actually made the urban sector better off instead. Now I suspect that in those three cases the model was gone over with a fine-tooth comb to find the mistakes. Eventually, however, the modelers were convinced that the models had no fundamental errors and that in fact their mental models had been wrong. If this conclusion was correct, these cases are evidence of some real learning. The modelers themselves had not made logical deductions from their assumptions. The computer did it for them, and the modelers learned from that process.

In another case, to provide a bad example, the same thing happened. The model produced an output that contradicted the expectation of the modeler. He never even noticed. The only reason I noticed was that my expectation was the reverse of his, so of course I caught the discrepancy right away. How could a modeler ignore the results of his own model? Well, it is important to realize that conclusions do not leap from the terminal. They come in the form of stacks of paper three inches thick, covered with numbers; and one has to look at those numbers very hard, organize them, and interpret them in order to make any sense out of them. And there mental models come in again. If the mental model is biased, as all mental models are, one can easily conclude exactly the opposite of what the numbers on the page are really saying. There may have been other examples in my sample that I didn't catch because my bias was the same as the modelers'. In other words, conclusions coming from a model may not be error-free. There may be simple, silly typing mistakes, or there may be, more likely, mistakes in interpretation.

EASE OF MODIFICATION AND VERIFICATION

My final claim was that *models are easy to change, to test, and to use for exploring alternate sets of assumptions*: I can say unequivocally yes, that is true for two of the models in my sample, the simplest and most transparent ones. It's easy to run those models through their paces, try everything, and see what happens. For the other seven, no. These models simply could never be adequately tested. They are too complicated. They are too expensive. Some of them cost several hundred dollars for one run, and therefore one is just not able to try fifteen different variations of something. There are too many exogenous variables that one has had to guess at, and in order to try every possible combination of guesses, one would have to sit at the computer for a million years.

By the way, eight of the nine models fitted historical data; (the one I mentioned that was unrelated to the real world didn't even try). Eight of the nine passed that basic test, but anyone who has ever worked with social computer models knows how easy that is to do. There are so many parameter and exogenous driving functions that one could probably fit the road plan for a mountain pass with most of these models, if one wanted to.

In fact I don't know any really rigorous way to test a complex social-system model, any agreed-upon method that tells one to have or not to have confidence in a model, or any systematic way of exploring all the possible outcomes that a model could produce. Unless the model is extremely simple, it can never be thoroughly tested.

In summary, I would say that, except for the few good examples I've mentioned, very little new information or understanding has come out of these models. You can assume that markets will clear instantaneously and watch this happen in 185 markets at once, but I don't really think you learn much in the process. The population models all make the point very elaborately that if the denominator of a fraction such as GNP per capita goes up, the value of the fraction goes down. But one doesn't really need a computer to figure that out. In the three cases I told you about, where new insights really were gained by the modelers, the insights were not transferred to policy clients of the model. That is, the model surprised everyone and called for a revision of policy, but in no case did the policy maker understand the reason for that, or change the policy. Only one model was really used, in the sense that policy makers looked at it regularly, conferred with the modelers, and adjusted their decisions according to what the model said. That model is the shortest-term model of the survey. It has a one-year time horizon; it is a linear-programming model which tells the Mexican government how to adjust various import-export or farm subsidies. It is a fine-tuning model. It does not question whether these should *be* quotas or subsidies, what their longer-term effects might be, or even whether the knobs that are being fine-tuned are really attached to anything important in the system. But that is the model that has come closest to telling policy makers something that they find useful to hear.

ADVICE TO MODELERS AND CLIENTS

How can we do better? I'm still convinced that although this is the current state of the art of computer modeling, it needn't be the final state. There is a real danger of throwing the baby out with the bath water and going back to oracles and crystal balls, but I think that we would be losing something potentially great in doing that.

The book we're writing contains two chapters on how to do better, one addressed to modelers and one addressed to the sponsor or clients of models. Most of the suggestions that we make are either scientific, having to do with basic knowledge of social systems, or managerial, having to do with the organizational setting of the modeling project. They are not computational; that is, we don't see that the constraints are the lack of bigger computers, better software, or more data. The more important constraints have to do with what we know about social systems, and how we interact with clients. I will summarize just a few suggestions here.

First of all, the use of social theory in computer models is very primitive. Social theory in general has advanced far beyond what is being incorporated in models; more social scientists should be included in these project teams, especially those who can cross disciplinary boundaries. There should be more basic research on how decisions really are made in social systems, especially research that involves going out and watching decision makers in action. The policy makers' urgent desire to know about the future has rushed computer modeling into a "Tell us right now" bind, and the modelers, flattered by all the attention, have been too eager to oblige. But the field is still new and infantile. It should be more of a basic research field than an applied research field. On the other hand, there are some applications that can be handled now, and the rest of my recommendations will deal with those.

Modelers in general, and also clients, should be aware of the methodological blinders that accompany each computing method. An input/output analyst looks at the world a certain way, he sees interindustry flows very clearly, but he tends not to see things that don't fit into an input/output matrix. Linear programmers see the world as sets of objective functions, activities, and constraints. Other sorts of biases characterize econometricians, or system dynamicists, or any other kind of modeler. Policy problems should be matched with the kinds of biases that are most likely to fit the problem. In fact this almost never happens; usually modelers unconsciously twist the problem so that it fits their method, and policy makers are not aware that this is happening until it's too late. I think Dartmouth College may be the only educational institution that has a beginning course on the philosophy of modeling, a course that looks at all the computer techniques and their blind spots, so that modelers-in-training are forced to confront the fact that different things tend to get left out of different kinds of models, because of mathematical convenience or the way you set up matrices. There should be much more of this teaching, for policy makers as well as modelers.

The third suggestion deals with one reason why modelers tend not to match policy problems with their methodological blindnesses. They're usually not presented with a problem that is defined clearly enough for anyone to really decide whether a given method fits the problem. This is a problem that begins with clients. The policy question must be defined extremely clearly before a computer modeler can attack it. The posing of the question must definitely precede contact with the modeler, so that the modeler won't redefine the problem to fit his method. Clients themselves should have some ability to pick a method that fits the problem rather than the other way around, but that first involves defining the problem carefully.

The worst model, if it's possible to define a worst model, in our set of nine was one that was asked to foretell nearly everything about the system. There was no defined problem, and therefore every imaginable variable was put into the model. The result can be run on only one computer in this country; it can't be set up at all in the country to which it was addressed. No one understands how this model works; it is a black box to which one addresses questions and from which one receives answers that one either rejects or accepts on faith. Nobody really defined what this model was supposed to do, so it does everything. Therefore it does nothing that is of use to anyone.

Another piece of advice — a difficult one — is that the policy maker should be involved in the modeling process as much as possible, from beginning to end. The process itself is where the learning takes place. It's in the going around and asking rigorous questions, trying to organize one's knowledge about the system, watching the computer runs come out, and deciding the model is wrong because assumption X is missing or assumption Y is wrong. The client's assumptions should be in the model — he usually knows the system quite well — and the client should understand the model, otherwise he will never use it. Involving the client in the modeling process requires a great deal of time from very busy policy people. They must work with computer people who may not even quite speak the same language. The process is difficult, but my advice to a modeler would be, if a client isn't willing to offer that time, don't do the model — because it won't be used anyway. Decision makers rarely respond to a hunk of computer paper plopped down on their desk a year after a study was commissioned.

My general advice to modelers is "simplify". Of course every modeler already knows that. There are all kinds of little jargony phrases that computer people tell each other about making the model simple. But they almost never do it; it's so easy to make the model complicated and so difficult to make it simple. Taking things *out* of the model should be a goal of every modeler. It isn't, and no amount of exhortation will change the situation. The natural end state of every modeling process is a product that is at least as complicated as the real world. I can think of only three strategies to counteract this tendency. The first has already been mentioned: define a limited, modelable problem, clearly and carefully. The second is to *train* modelers in how to simplify. I'm working on that here at Dartmouth. The third strategy is to offer a limited budget and a strict time constraint for the modeling process, with no extensions.

Two more quick recommendations. One, when the model is finished, give it to your greatest competitor or rival to test. I did that inadvertently once and learned a lot about my model that I never would have discovered by myself. People were trying to disprove it, put it through paces and push it into corners, doing things that I never would have thought of trying. That model is the best-tested one I know, simply because it was the opponents who did the testing.

The last recommendation: document the model in plain English. If I could write a bill of rights for clients, it would begin, "You have a right to have the model explained to you in language you understand." Most clients don't insist on that, they don't pay for it, and therefore it doesn't get done. It takes an unbelievable amount of time and effort to do, especially if the model is a complex one. And it means the modelers themselves have to understand the model first, which they don't always bother to do. It also requires a sort of effort modelers don't like; they usually have been trained to model, not to write. There is a movement in Washington to set forth documentation standards for any federally-financed model. I have another suggestion: half the payment for the model should be contingent on the presentation of documentation according to standards. That should improve the field greatly.

I really believe that the sorts of improvements I suggest are possible. I don't think they can be done instantaneously. I think they can lead to better models — more useful models and more used models — and ultimately to better social policy, which is what I'm really interested in. In fact the ideal result, as far as I'm concerned, would not just be a more rational and systematic oracle for policy makers. I am looking for a people's oracle, one that most people could comprehend, interact with, try their assumptions on, and criticize. Everyone could understand the assumptions underlying the social policy that affects him. That really would be something new in human history — a rational, demystified, democratic oracle.

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ABSTRACT

As a consequence of numerous growth factors, the burden placed on the federal government to meet its constitutional obligations has increased. Social concerns, economic complexities, environmental factors, international affairs, status of human rights and national defense are all pressing issues which have an impact on individual lives. Through creative use of computer systems and judicious human management, the capacity for effective political performance at the federal level can be increased.

Computing as an Aid to Political Effectiveness

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Let me say at the outset that I am not an official politician. I've never been elected to an office of any sort. But I've learned in the six years that I've been at the House of Representatives that my background in professional football ably prepared me for work there. Having weathered the internal politics of a very political place, I'm going to talk to you today about computing and politics.

First, it appears to me that computing and politics interact in a couple of important, general ways. Each enjoys a broad integration with many aspects of our life: science, commerce, institutions (including government); yet neither is fully understood by its practioners or by the society it serves. This is a problem to which I will attempt to give further shape in my talk.

To illustrate this problem, observe that politics follows the federal bureaucracy to just about every sector of our public life; yet in the 1976 elections half of the 160 million citizens eligible to vote did not — they did not exercise what is perhaps their most important political activity. As for computing, we're all familiar with its propagation. It gets into, and perhaps into the way of, almost every operational environment of any size and complexity. It is tenacious; in fact, some industries depend on computing for their existence. But the advance of computing is not without its problems. For example, the privacy issue perplexes the public and, I think, confounds the computer advocates. In the more specific interaction of computing with politics — I'll get to a few examples later — these two natures, being pervasive and being complex, present a great opportunity for broad benefits. But at the same time there is the peril of misconceived applications nurtured within a misunderstood environment.

I should hasten to say what I mean by *computing* and what I mean by *politics*. I'm not going to belabor the point about computing, which I take to include, broadly, input/output devices operating under program control, their data bases, and data communications. It's a very large spectrum of applied technology. By politics I mean the policy adjunct to government that operates at the federal level. Some people refer to it as "the catalyst of government."

There are two ways of putting the question, how do computing and politics interact? On the one hand there is the application of politics to computing, in which the inquiry is governed by consideration of normal political methods employed to resolve policy on computing-related issues that arouse societal debate. These issues currently include privacy, aspects of the Bell Bill, electronic funds transfer, computer crime, etc. In these cases, computing confronts politics with a problem only to the extent that the political mind fails to understand computing implications. The problem has its resolution in a more perceptive understanding of computing. In this sense computing is no different from other policy issues, such as environmental concerns. The political issues surrounding environmental concerns are complex and confusing; they raise the question as to whether we understand environmental parameters well enough to be setting policy about them. We can thus expect *some* societal perturbations to result as policy on environmental concerns is developed. The same goes with setting policy about computing. In summary, in situations where politics is applied to computing, there appears to be no new dimension to politics introduced by its consideration of computing-related issues.

It's the other side of the question that provides computing with a great challenge and adds new dimension to politics. The application of computing to politics, to the political mechanisms themselves, is my special interest in this talk. I'll give three examples to illustrate how computing has influenced politics, then draw some general conclusions.

Political mechanisms generally provide for the reconciliation of competing interests to achieve a consensus — this is another way of describing politics. At the federal level these political mechanisms work within the framework of the Constitution and its laws. Reduced to its fundamentals, politics is a human activity not governed by specific rules. James Madison recognized this in 1787 when he wrote a newspaper piece in support of the Constitution (see *The Federalist Papers*, No. 51). He saw then that human nature was inherent in politics, and he wanted to be sure that our government accounted for it. He said,

> Ambition must be made to counteract ambition. The interest of the man must be connected with the constitutional rights of the place. It may be a reflection on human nature that such devices should be necessary to control the abuses of government. But what is government itself but the greatest of all reflections on human nature? If men were angels no government would be necessary. If angels were to govern men, neither external nor internal controls on government would be necessary. In framing a government which is to be administered by men over men, the great difficulty lies in this: you must first enable the government to control the governed, and in the next place oblige it to control itself.

My contention would be that use of computing has the potential to warp James Madison's intention.

We know that political intention often finds expression in compromise, and not infrequently political reality accepts the philosophy that the end justifies the means. Nixon's Watergate disaster exhibits both the extreme consequence of this method, and — saving the day — the self-correcting strength of our political design. Ambition and political conscience joust in fulfilling the Constitutional mandate, whether it is in election politics, or in congressional politics, or in the political stress that exists between the legislative branch and the executive branch.

Computing has been vigorously projected into the political method, for example in economic forecasts. The computer used as a tool to assist political processes suggests that there is a discipline or a science that underlines its use in that environment, and this apparition of irrefutable logic is often welcomed by politics; yet claim for such an underlying discipline is unwarranted by the very nature of the political process in which it is embedded. The political environment, with its propensity for image and appearance, for structured argument, for authority, for exaggerated claims, can find benefit through artful computing. The question is whether the political benefit so derived is indeed a public benefit.

You might ask at this stage how computing applied to politics is different from computing applied to other endeavors. Well, we know that computer systems can't operate in isolation; they are an interactive part of the environment in which they are embedded. In the case of politics this environment is often characterized by the mediation of competing and contrasting interests in the development of supportive or one-sided arguments and by the compromise of objectives within a structure that ostensibly provides a check and balance on its various enterprises. That is to say, the environmental context of a computing system integrated within a political mechanism is essentially explained once the political intention of the application is perceived. Thus politics presents an ever changing context with intuitive, rather than definitive, foundations for computing applications. In this arena, the computing system may indeed be nimble if it is to serve political intention effectively.

IN ELECTION POLITICS

Computing has been applied extensively to activities associated with election politics — this will be my first example. To begin with, a little background. Election activities were considered a very important part of our Constitutional framework. By design the founders sought to ensure dependence on the people by requiring frequent elections. In this way the officeholders were periodically evaluated on their execution of the public trust, and at the same time elections provided the opportunity for the infusion of fresh ideas and skills. Our republican form of government, in which the people elect their representatives, is aimed at modulating the interests of individuals. Madison addressed this, too, back in the good old days. This modulation of individual interests was to occur by passing them through the medium of the chosen body of citizens, "whose wisdom may best discern the true interest of their country, and whose patriotism and love of justice will be least likely to sacrifice it to temporary or partial considerations" (see *The Federalist Papers*, No. 10). Thus it was hoped that special interests and individual influence on the part of the people could be subjugated to the common good.

Yet there is a concern these days that there are at work strong forces tending to throw out of balance the concept of election politics that Madison gave to our Constitution. The election process has been modified extensively, not just by computing, but also by other technological developments: TV, the advertising method, etc. Senator Robert J. Dole (R-Kansas) recognized the threat several years ago when he was Chairman of the Republican National Committee. He stated (in *The Political Image Merchants*, 1971) that " . . . our free political system, if it is to survive, depends not so much on a convinced electorate as on an informed electorate. An informed electorate can be convinced on the merits of a case; a properly propagandized electorate may be giving temporary victory to one party, but the people and the Republic lose in the process."

What role has computing played? In the 1976 campaign, as you may have read in various articles, both of the major parties used computing extensively, and I think very effectively. The spectrum of applications included fund raising, voter registration, opinion analysis, target communications, precinct field work, financial reporting and expense itemization, information search, campaign logistics, and coordination of candidate statements — the latter in the case of Carter and Mondale when they were traveling their separate ways and wanted to be sure they were on the same page, so to speak, when they were making their public utterances. If you examine these applications you will find that they are fairly straightforward and ordinary from a computing point of view, but in the large they represent a great strength for those who were using them. You might say that one campaigner was using it against the other — and of course that is exactly what happened. I can tell you that Carter's campaign did utilize time sharing and remote terminals; Ford's used batch only. And of course computer methods were not used just in the presidential elections. They had their smaller applications in the House and Senate campaigns. Thinking about this, it appeared to me that computing had added greatly to the campaigners' ability to convince, but little had been done to help create an informed electorate. There's a shade of difference in this distinction that makes *all* the difference.

At the same time the expense of campaigning has become a very critical problem. Computing contributed only partially to this problem in 1976 (for example, it was reported that the Carter campaign had spent about $750,000 on computing). Yet some of the contenders in the Democratic Primary canned their campaigns because they didn't have enough money to go on. A conflict with the Founders' purposes arises because it was certainly their intent that "no qualification of wealth [of the candidate] . . . [be] permitted to fetter the judgment . . . of the people" (*The Federalist Papers*, No. 57). The wealth question is not a computing question, you might say, but certainly the use of computing is expensive and it adds to this problem.

There are other considerations. The fact that you have a large mailing list that is personalized to a small subset of your constituency is not the way the grand scheme of our Constitutional framework was supposed to work. It was not intended that a special interest group would get the ear of their representative. Yet if you are in the representative's data bases and your friend is not, then you have a special channel of communication to the representative.

So I perceive in this broad area of election politics that computing has come to the fore; it has helped — it's done a job. But I don't observe a parallel concern for the full political consequence of the use of computers.

AT THE HOUSE OF REPRESENTATIVES

My second example deals with a computing application at the House of Representatives. Computers are used there to assist the legislative process in many ways. One particular mechanism that has been "computerized" is voting. The House members now use a computer system to cast their votes. Previously, they spent so much time calling the roll alphabetically that the need for a system to reduce time spent in voting was apparent. This system involves vote stations scattered around the House Chamber: small devices attached to seat-backs which permit an ID card to be inserted and a button punched to cast a vote. A member can vote from essentially any place in the Chamber, which is analogous to the traditional method that permitted a member to respond by voice from any spot in the Chamber when called by the tally clerk. The advantage lies in not having to vote in the alphabetic sequence as before, but in a rather random fashion whenever it is convenient to do so within the alloted time period, which is fifteen minutes. The system is more complicated than a simple tabulating system. It involves CRT's placed on the floor that are used by the leadership and those concerned with in-progress vote information to determine how subsets of the members are voting. For example, at ten minutes into the voting period the leadership could see how the Democrats from California are voting en masse. Or they could observe how Republican members of the Science and Technology Committee are voting. This is important because there is a traditional need for revising strategies while a vote is in progress. The computer was essential in order to automate this function.

The new voting system gave a twist to the traditional political mechanism of voting; several new wrinkles were encountered. For example there were instances of gamesmanship in which votes were changed right at the end of a particular voting period. You can readily see what happens when the member wants to follow his conscience on an issue, but the leadership has a claim on him and has asked him to support the opposite side of the issue. As the voting period comes down to the last seconds, he sees from the running tally that the leadership is going to win and consequently doesn't need his vote. So he goes to the vote station and changes. The ease of doing this threw chaos into the last few seconds of voting on tight issues. Subsequently the House rules were modified to eliminate vote changes in the last five minutes: the member would have to wait until the vote period is over to change his vote, and then only by making a voice declaration to that effect. More importantly, the automated voting system threatens to nullify the original intention, which was to cut time spent by members voting. Surely it accomplishes this on each individual occasion, but it has made voting so much easier that many more votes are recorded now, with total time spent on voting in the Chamber approaching the total time previously required for fewer votes. Wayne Hayes, who is responsible for authorizing the system, was very upset when he discovered this. He claimed that if he had it to do over again he wouldn't.

BRIDGING GAPS BETWEEN BRANCHES OF GOVERNMENT

I will mention one final example very briefly just to illustrate how computing has literally bridged the gap between the legislative and the executive branches. The Joint Committee on Internal Revenue Taxation (JCIRT), which is responsible for tax law, uses an individual income tax model to run projections of revenues to be generated if the tax law were changed in various categories. They have a very competent staff who make this analysis and advise the Joint Committee on its legislative direction. The computer on which the model runs is in the Department of Treasury, and the model makers are executive programmers working for the Department of Treasury. Until recently, whenever the JCIRT desired a revenue estimation connected with some particular question of tax law, the JCIRT staff would describe to the executive programmers the desired analysis parameters and would receive in return output from the model. Of course this put the Treasury Department in an enviable position when hearings on the tax law modifications were debated. In effect, they could play against a tipped hand, knowing in advance what the JCIRT was after. Recently this situation has been changed slightly with the installation of a remote-entry terminal mechanism going into the computer, so that Treasury Department programmers are no longer required to assist the JCIRT in running the model. But Treasury is still responsible for the model and is in control of the equations on which the model is based.

Is this the check and balance between the two branches that was envisioned by James Madison in his day? (Of course, he didn't realize that computers were coming; though he was such a great thinker that if he had thought very hard about it, he probably would have anticipated them.) I think not.

SOME POLICY QUESTIONS

The modification of political function through the "easy" use of computing brings with it a potentially harmful compromise in the political design on which our Constitution is based. I don't say that we shouldn't use computers; I think we should. But someone should be concerned about these questions:

- Can computing through its functional strength undermine the controls envisioned by the Founders?
- Can computing through its highly entrepreneurial and evolutionary character force unforeseen bias upon the political processes that come to rely upon it?

The burden of resolving such questions rests in the abstract on computing science, but in a practical sense it goes to the heart of how the political architects of our day are going to treat computers. Let me offer two thoughts, one toward the abstract resolution, the other toward the practical resolution.

In the abstract, my feeling is that we're missing a very important ingredient in computer science: a *discipline* for computer applications. Work needs to be done to define the general nature of the environments into which computers are injected, a definition that should be achieved before the computer is emplaced. If we take reality (whatever that is!) as our base line then we might seek to create a conception of that reality in terms of a model or a scheme, what I would call a *reality scheme*. The worthiness of this scheme as it relates to "reality" would essentially depend on human wisdom, which is a philosophical issue. We might then identify an important class of these reality schemes, called "closed schemes." They would have the property that whenever you perturb or transform a component within the scheme, the essential features of the scheme would remain invariant. If this abstract concept were possible, one could replace (i.e., perturb) a component of a closed scheme by a computer application with the expectation that the "real world" features would be essentially unchanged. It might shift a bit, but in the large it would remain invariant. In this context the discipline for computing applications would be derived from the properties of a related reality scheme. I think the quandary about EFT suggests the need for such an approach. There is of course no reality scheme for the political environment, at least not at the federal level — I haven't looked elsewhere.

That brings me to the practical thought, which deals with the role of the political practitioner in a computer-wise society. If unplanned consequences of computing are to be eliminated, some entity of a political sort needs to take responsibility for developing the reality scheme for politics. An analog of this happened when James Madison, John Jay, and Alexander Hamilton wrote the *Federalist Papers* in 1787. They created a concept that explained and clarified the Constitution and its role in American life. But of course there were no computers or TVs or their side effects, in 1787.

One thing that computing can offer in this direction, I think, would be to help political philosophers update the *Federalist Papers* in the context of our modern political realities and technological capabilities. For example, going back to the check-and-balance concept of our government, one can visualize a future scenario in which there exist in the three branches organizations specifically concerned with the use of information systems, so that a check and balance on information use among the various branches could be accomplished. In the near future, perhaps the best we can achieve is to raise the issue and hope it becomes a political concern.

I can tell you quickly that my organization is going to help install a computer network to all the members' offices in the House and Senate. The network is going to pipe to them a number of information products that conceivably will give them great strength. There's no question that computing will enable this network to be an outstanding, modern day event for the Congressmen. Unfortunately I don't think we know enough yet to say whether its emplacement in that environment is going to create a negative political consequence in the future that we can't foresee right now.

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ABSTRACT

Computers will never be completely accepted as useful partners to man until risks associated with their use are understood. The concept of risk, acceptable risks, vulnerabilities and safeguards will be discussed.

Taking Risks With Computers

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One of the problems with which a civilized society has the greatest trouble is that of dealing with *risk* or danger. The more primitive have the least trouble — direct confrontation with the enemy in front of a cave, physical destruction of a city or an artifact, such as a statue or a machine, are very tangible, satisfying ways of handling a threat or a fear. Some of us still handle our problems in this way; most of us do not.

Science and technology provide us with one of our greatest dilemmas. As a society we admire, respect and envy scientists and science. But the products of science and technology confuse us. If we dislike or fear them, there are very few civilized means at our disposal for dealing with them. Also, we are very poor at anticipating technologically-induced risks. Consider a few.

The automobile generated a new era of crime. The criminal from outside the neighborhood, even outside the town, appeared, along with the quick getaway. The automobile kills about 50,000 people a year on highways. We have individually and collectively *assessed* the risks posed by automobiles in terms of danger to our lives and property through accident and crime. Yet we drive them daily, increasingly, and require a minimum of licensing for ownership and control. Their advantages to us obviously outweigh their disadvantages.

The telephone line offers superb opportunities for misuse. The telephone receiver itself is an excellent holder of passive eavesdropping devices in the home — undetectable except by physical search. Here again, we have individually and collectively decided to have phones and phone lines — in fact there are some 109,000,000 telephones in the United States alone. We have made it apparent that we want phones more than we fear them.

The scenario gets a bit less determinate as we view other products of science and technology — but perhaps the confusion exists because today we are just closer to the beginning and have not had as much familiarity with some other products of technology such as nuclear power, computers, and manipulation of the protein molecule to yield seemingly resistant viruses.

If we concentrate just on computers, we see a collection of strong beliefs; genuine interest; amorphous, free-floating anxieties and highly articulated concerns.

The more amorphous anxieties seem to settle around two quite different aspects of computers. The first is that computers will become smarter than man; man will be an inferior being and not the superior species of today. Indeed, despite many popular and sometimes expert statements to the contrary, no one, as far as I know, has demonstrated any intrinsic limits to what computers can do.

The second of these somewhat amorphous anxieties centers around possible dehumanization through computers. This fear appears to be dissipating in direct proportion to the amount of contact individuals have with computers. The computer vending machine and the computer hobby shop have been singularly successful in dispelling this particular anxiety and replacing it with a healthy admiration and liking for the potentials of computer technology.

A more articulated concern expressed about computers has to do with a fear of loss of individual freedom and control over one's destiny. Public perceptions of loss of freedom of action manifest themselves in concerns about pervasive surveillance. For example, there has been criticism of proposals for the implantation of transmitting devices to monitor the movements and activities of paroled prisoners. Checking of police records for individuals picked up on ordinary traffic violations has evoked the image of constant surveillance.

Loss of freedom may be sensed when computers are used for functions that had previously been strongly under local control. One especially interesting application of computers where a balance must be struck between computer use and localized freedom of action is that of computers in elections.

About ten percent of the American voters today use punched cards as a voting medium. More than 30 states have passed legislation permitting punched card ballots. Of the 100 largest U.S. cities, 16 used punched cards in the 1972 presidential election. In the 1972 presidential election, about 2.9 million voters in Los Angeles County used punched cards. The system is more pervasive in the western states: California, Oregon, Arizona, and Hawaii.

Only a few election districts using machine-readable ballots and/or computers have experienced major difficulties. A study of computerized elections conducted by the National Bureau of Standards concluded that failures of management have been responsible for most of the difficulties experienced in vote-tallying, e.g., failure to institute adequate equipment and procedure testing and checkout; human operational failures, such as errors in operation of computing equipment; and technical failures, such as computer program errors and excessive card jams in card readers. Sudden technical failures, not predictable or capable of being considered in advance, have not been a significant factor.

Our current efforts to report election results speedily and accurately are in sharp contrast to the old days of strong local control. At a recent symposium held at the National Bureau of Standards for election administrators interested in computerizing their elections process, Commissioner Neil Staebler of the Federal Election Commission told a delightful story about the old days. He described a small voting jurisdiction in Michigan that was known for its consistent and long-standing record of support for the Republican Party. When the votes were counted, by hand, the local Republican Party official watched the tedious process of opening each ballot and announcing another vote in the Republican column. At last he fell asleep as the process continued. While he was sleeping, the counters discovered a ballot that had been marked for the Democratic Party. Believing that this was a matter to be brought to the attention of the official, the ballot counters woke him up to tell him. The official considered the ballot, and said, "Let's set it aside, and continue the counting." As the process continued, he again fell asleep, only to be awakened again when the counters discovered another Democratic ballot. They woke the official again and told him the bad news. "Ah, that explains it," he said. "This fellow voted twice. Disqualify the vote."

Other public concerns with computer and information misuse have manifested themselves in the last five years primarily as concerns over:

- Invasions of individual privacy
- Centralization of information control, e.g., as with the FBI and state/local governmental controls over criminal records

- Damage to individuals resulting from inaccuracies in credit records
- Increasing surveillance over our personal activities
- Controlling unlawful access to and unlawful use of "valuable" information; for example, in electronic fund transfers, agriculture commodity listings and health records
- Risks of dependence upon computers where life or property is at stake; for example, in air traffic control, electronic fund transfer systems and intensive health care units
- What the future holds in terms of robots, a "big brother" society, dehumanization or technological monsters
- Computer fraud

For example, concerns for individual privacy have been aroused as more and more personal information is collected and stored by computers, and computers are applied to the extensive record keeping required for our complex society. Some examples of personal information records which have increased significantly in number since 1940 pre-computer days are:

RECORDS	PERCENTAGE INCREASE BETWEEN 1940 AND 1970
Motor vehicle registration	230%
Airline passengers	5,600%
Passports issued	8,362%
Social Security payments	11,702%

(Excerpted from *Crime by Computer*, Donn B. Parker)[1]

We really do have difficulties in our civilized society, as was pointed out earlier, in handling public concerns with possible misuses of technology. We can regulate, legislate, make decisions in courts; we can strike, form consumer advocacy groups; or perform acts of violence and sabotage. One computer was shot four times with a shotgun just four years ago as an expression of outrage.

The Lordstown, Ohio, Vega plant — newly opened six years ago and making extensive use of industrial robots — was so damaged by the workers' acts of sabotage that it had to be shut down.

We have two congressional laws dealing directly with computer use. They are: (1) The Fair Credit Reporting Act of 1970 and (2) The Privacy Act of 1974.

Nevertheless, I do not believe that any of us is satisfied with the present haphazard way of dealing with our technologically-induced fears. However, we are seemingly becoming not only more sophisticated in our ways of applying computer technology and of translating our concerns into legitimate actions but are becoming less "up tight" about computers and robots. What is still lacking is a realistic treatment of the risks associated with computer systems.

THE CONCEPT OF RISK

I should like to treat the concept of risk and, in particular, to concentrate on our present mode of taking risks with computer systems. I have become convinced that in our design, development, installation and usage of computers in the last 25 years there has been a lack of a real grasp of what risks are involved with the use of computers.

The problems we have had and the troubles we face as we watch the increasing diversity of computer applications are, I conjecture, largely traceable to our present inadequacy or unwillingness to be accountable for the safety of computer systems. We have not yet faced up to answering the simple question: "Computers are more dangerous than WHAT?"

Until computer professionals provide the scientific and technological basis for decisions about dangers, safety, risk and cost, the key question above will be answered on the basis of emotion, prejudice, protection of special interests, political expediency and all the other suspect motives that thrive on the lack of scientific truth, technological fact or experiential data.

The problems encompassed within the rubric of computer security and the damages resulting from intrusions into individual privacy are probably the most visible manifestations today of this festering ineptness for addressing the simple basic questions bothering individuals, either when they are part of the public or part of the management/policy-making sector.

Those who tell us that the privacy issue is being overplayed, those who tell us that computer security is simple to attain and easier to ignore, and those who lull us by stating that costs of compliance with privacy requirements are always overestimated may be right "in the small", but they are very wrong "in the large." For privacy and security are just the beginning telltales of the realization that we do not know how to judge the safety of computer systems; that is, we do not know how to tell (1) when a computer system is *not* performing its *intended* functions, or (2) when a computer system *is* performing a function which was *not* intended.

As long as we operate in this never-never land of ostrich-like behavior with absence of truth, fact and observation, we will be suspect as a profession, and computers will be suspect in their operation.

On the other hand, there are those who point out that dealing with computers in terms of risks involved may provide a one-sided, negative indicator of computer worth. I do not think this to be the case. Rather, I think that looking at the risks associated with computers is a very beneficial way of discussing the problems of computers. The beneficial aspects are twofold: first of all, it appears to be a healthy countermeasure to 25 years of selling computers based on a somewhat naive approach, that any use of computers is an improvement over existing ways of doing functions. Second, looking in a very pragmatic way at what risks are involved in using computers should enable us to highlight the benefits of computers. We should be able to compare the relative utility of computers to other alternatives, and the risks associated with performing functions using computers to the risks associated with performing the same functions by other means. It is in the context, then, of attempting to pursue a realistic approach to computers and to highlight the relative benefits and disadvantages of computers that discussions of risks and risk taking with computer systems become very attractive.

There is also something very appealing about the concept of risk. Through its use, we can delineate the various responsibilities of the several groups in society that are concerned with computers and computer use. For example, the fears of the public can most easily be presented by public representatives and advocates if they can be translated into the kinds of risks that the public fears from computer systems. If fears cannot be translated into something as legitimate as risks, then they remain amorphous and free-floating anxieties to which it is very difficult for responsible managers and scientists to respond.

Secondly, the concept of risk allows one to describe vulnerabilities of computer systems and the dangers associated with the use of computer systems. Then, again translating these into risks, one can ascribe safeguards that can be used to combat or to avoid vulnerabilities or dangers. Again, a most important factor in discussing problems of computer systems in terms of risks is that one can associate risks with costs. The cost of alleviating the risks of computer systems through the use of safeguards can be compared with the cost to the public or to individuals if the risks cannot be eliminated through applying safeguards to computer systems.

Most importantly, it is going to be absolutely essential to come up with acceptable levels of risks in using computer systems for the performance of functions. The idea of deciding on acceptable levels of risk, although new to the computer professional, is in no way new to scientists or to the public. It is indeed comfortable to people, scientists, economists, and lawyers to talk in terms of risks. Furthermore, it appears to be a very useful way to bridge the present communications gap between computer science and society if one can use a terminology which is comfortable to all concerned.

The determination of acceptable risks appears to be something with which we are all comfortable. Take, for example, the act of driving a car to work every day: we have made an individual determination that there may be a risk associated with driving, which can be translated into the danger of fatal accidents or the fear of death. However, at the same time a concept of safeguards that we impose on our own driving ability allows us to decide individually whether or not it is acceptable for us to drive a car to work. Similarly, we have become used to analyzing the risks associated with nuclear power used for national defense or for generation of electric power. We have become accustomed to trading off the risks of possible explosion or a possible nuclear holocaust, with the benefits of national defense or readily available electric power.

RISK AND SAFETY IN COMPUTER SYSTEMS

The action of attempting to manage risk and to determine safety is not a familiar one to computer scientists. Exceptions that come immediately to mind, of course, are those computer professionals involved in weapons delivery systems, space systems and traffic control.

In his recent book, *Of Acceptable Risk*, William Lowrance provides an excellent treatment of this topic, still somewhat alien to the scientific and technical community. I shall adopt his definition of safety, paraphrased to match our interests, namely: A computer system is *safe* if its risks are judged to be acceptable.[2] Then I will define risk as follows: *Risk* is the probability of loss or damage due to the occurrence of undesirable events or adverse effects.

The determination of safety or an acceptable level of risk then becomes a judgmental decision. Using the elements of Figure 1, we can say that the determination of safety (or an acceptable level of risk) is a consensus-driven decision process in which public concerns, dangers, vulnerabilities, the costs of safeguards, and comparison of alternatives are all

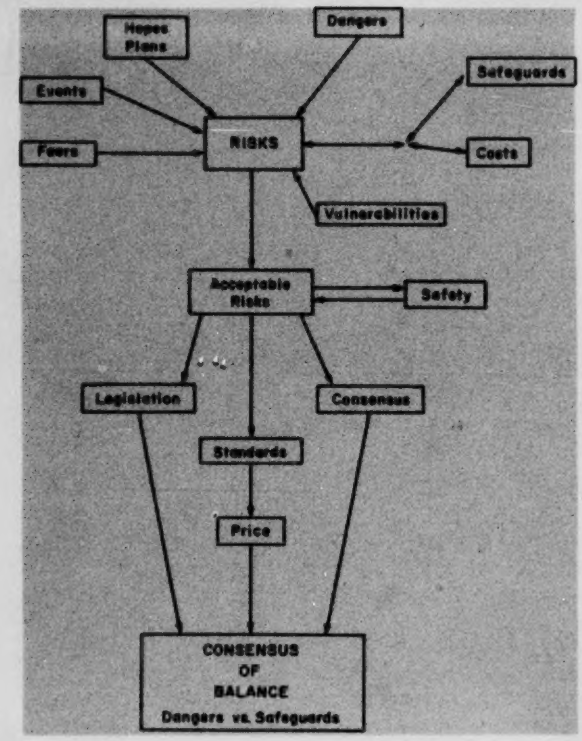

FIGURE 1

The Safety-risk Management Process

factored together to yield a result. The required safety or acceptable level of risk is then normally imposed or sanctioned through legislation, regulation, standardization, or some combination of these. We saw the process at work, after a fashion, in the Privacy Act of 1974. An earlier, less publicized instance occurred in the passage of the Fair Credit Reporting Act of 1970.

What we do not know now is what activities and projects are underway in each of the areas identified within the risk management cycle (see Figure 1); not knowing what is happening guarantees that we cannot direct our efforts nationally so as to meet high priority needs. Ignorance of what is on-going guarantees a less than acceptable allocation of resources and an inability to highlight an urgent need for resources in any given area. This is an untenable situation, especially among computer professionals whose services and products are advertised as superb aids to better management. The axiom "Clean thy own house first" comes immediately to mind.

At the National Bureau of Standards, we are now trying to untangle the tangled web of government-sponsored research and development (R&D) in computer security and risk management. Our immediate objective is to simply identify and categorize R&D efforts underway against a listing of objectives such as that shown in Figure 1:

- Public fears
- Dangers
- Vulnerabilities
- Adverse events
- Costs
- Safeguards
- Acceptable levels of risks by high-risk area
- Standards
- Planned future system architecture, system configuration, etc.
- Allocation of costs to customers
- Legislation
- Regulations
- Management options
- Achievable balances (dangers vs. safeguards)

You might properly wonder why we do not know. I would, as a concerned modern-day Diogenes looking for the truth — with a pencil, set of questions and a pad instead of a lantern — suggest that you keep asking why we do not know. For until we do know, we will be crippling computer applications and advances and will be negligent in our accountability to the public. I submit that we must be able to honestly answer the questions: "Computers are more dangerous than WHAT?" and, "Computers are more beneficial than WHAT?"

As we learn more about what is going on in computer system safety and risk analysis, we can assign priorities to unanswered problems and begin to make measurable progress.

My premonition at the moment is that we are:

- Unjustifiably weak in realistic cost estimates for proposed safeguards;
- Just at early primitive stages of describing system vulnerabilities and matching them against resultant adverse effects on the one hand, and safeguards on the other;
- Totally naive in our understanding of how to describe and discriminately handle information of varying levels of sensitivity;

- Lacking in our ability to suggest realistic standards, regulations or legislation to impose acceptable levels of risks which can be based on technical data and experience.

IDENTIFICATION AND SPECIFICATION OF HIGH-RISK AREAS

Inability to cite high-risk activities almost inevitably leads to diffusion of attention which, in effect, equates to *inattention*. And indeed, such inattention may be exactly the scenario of today — 1976. A public and management "bird's-eye" view seems to me to reveal as areas of high risk:

- *Large funds disbursing systems*
- *Large individual information systems* (especially those providing evaluative services on individuals) e.g., credit reporting systems, educational institution information systems, patient record systems, law enforcement systems
- *Large public safety control systems* such as air traffic control systems, plutonium accountability systems, nuclear power plant control systems, law enforcement systems

Generally, computer activists have concentrated on the problems of security of large individual information systems, from which the privacy problem has evolved. Without any decrease of attention to this high-risk area, increased attention needs to be directed toward the other suggested high-risk activities.

Most of our accumulated attention to date has been directed toward statements of generalized concern and toward highly articulated gross complaints. I do not want in any way to be critical of the common human tendency of the 1970's to complain, accuse and confuse on major issues. Nevertheless, complaining is but one part of the problem-solving process; and I would conjecture that too few of us are concentrating on the other, less publicly visible steps in the process.

We need to expedite the isolation of specific risks and the identification of the consequences and the costs of their continued existence. Several fictionalized examples of specific risks within the previously listed high-risk areas might be:

- A 10% increase in the expected cost of health care payments due to inclusion of ineligible claimants
- A 25% probability that enough plutonium can be consciously obtained by an improperly motivated individual within a year to "build a bomb" due to the round-off errors in the plutonium accountability system at nuclear plant site X
- A 5% probability of loss of scholarship opportunity by students due to lack of control over inputs to school record systems: a loss to the wronged student of $30,000 of educational benefits
- A 20% probability of two planes being within collision distance when the aircraft density within 100 miles of an airport exceeds a specified level
- A 30% probability of error in the credit record of any individual possessing more than three credit cards

Implicit in these fictional risk (rather than science fiction) scenarios is the assumption that computer systems are the control or information handling elements of the relevant organizational activities.

The costs to the consumer and/or the manager of allowing such fictional risk scenarios to continue should be assessed; similarly, the costs of reducing the risks to an acceptable level must be ascertained. If experience is any teacher, all risks are not simultaneously eliminated, all privacy problems are not resolved with equal dispatch, and all computer security problems do not lend themselves to the same ease of solution. A planned step-by-step phasing of corrective actions is essential.

The intent of such specific risk identification is to derive a widespread consensus on priorities for reducing risks, taking into account both the related consequences and costs. No responsible set of agents for so doing exists in the private sector. The situation is somewhat less depressing in government when the function in question falls within the mission of a given agency, and when the National Bureau of Standards (NBS) and the General Services Administration (GSA) under their central computer management responsibilities are addressing the problem. Otherwise, the means for action is equally as confused as in the private sector.

CONCLUSION

Hopefully, an acceleration of our efforts to look at the risks of computer systems will discipline us and structure our efforts so as to overcome past deficiencies. In our own defense, I think we can and should point out that there has been no steady direction or understanding of realistic goals by the large and growing computer customer community or consumer advocacy/adversary groups. Computer professionals, customers, advocate and adversary groups, professional societies, vendors, and the government in all three of its branches have together been floundering and passing each other in the night in less than commendable attempts to substitute goals for prejudices and to substitute progress for protection of special interests.

It may seem to many of us that computer professionals can do nothing right today in the eyes of the public; but I suspect the real truth is simply that we cannot make progress fast enough. Thus, I would conjecture that as computer professionals, we have a real mandate to accelerate our efforts in making computers safe and in setting acceptable levels of risk.

Further, all evidence points up that we should be doing this to the limits of our understanding and of our resources, and with the full involvement of the public and its spokesmen.

REFERENCES

1. Lowrance, William W. *Of Acceptable Risk*. Los Altos, CA: William Kaufman, Inc., 1976.
2. Parker, Donn B. *Crime by Computer*. New York: Charles Scribner's Sons, 1976.

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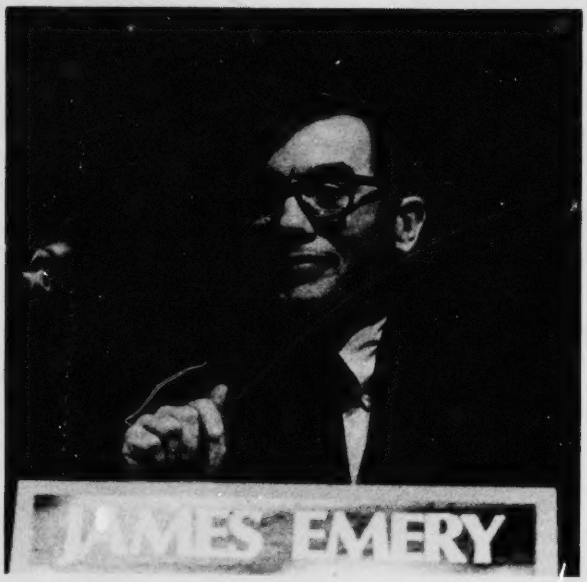

ABSTRACT

Colleges and universities see network sharing of the computer resource as a means of gaining certain economies and avoiding duplication of programs and data bases. Perhaps their greatest potential benefit, however, is the fostering of informal, collaborative arrangements among geographically dispersed professionals working on common problems.

Networks: A Link to the World Around Us

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Computers have the unfortunate reputation of being inhibiting and stifling, for reasons that were very well described by Ruth Davis and others. In fact, though, when computers are used properly they can be liberating. I would argue, given my bias these days, that networks can be enormously important in liberating us from the constraints of distance and from the particular organizational affiliations that we happen to have.

All networks have some sort of communications links, but their topology may vary widely. On the one hand, we have highly centralized networks with a single computer center linked through communication lines to remote terminals — perhaps relatively "dumb" terminals without much intelligence or logic of their own. On the other hand, we have highly decentralized or distributed networks with multiple computer centers that are almost completely autonomous, which are connected to the network in order to exchange services. My particular orientation is toward this latter end of the spectrum. I come with a particular bias in developing networks for higher education, where the nodes on the network are operated by autonomous universities.

REASONS FOR SHARING COMPUTER RESOURCES

Let's look at some of the arguments for sharing computer resources. To some extent, I think, one can justify networks on the grounds of tangible economies. There has always been interest in using a network to achieve economies through load leveling or backup of local facilities, analogous to the use of a power grid in electrical generation. There are certainly potential economies from the avoidance of duplication of hardware, software, and data bases. There are also some circumstances in which economies of scale can be important, particularly in the case of specialized resources that in their own local market could not justify large-scale computing but might justify it if they could serve a national market through a network.

Economies of this sort will, however, not be the primary justification for a network. The real benefits will come from capabilities that we simply could not get except through a network — the ability to access resources that each individual institution could not maintain on its own. This is particularly important for smaller institutions. Large institutions have the resources to develop a fairly full range of services for their members; smaller institutions do not. But even a large institution cannot possibly remain self-sufficient and still provide all of the services available to the academic community as a whole. Many of the more specialized services may be built around a special person or a special research group. If one wants access to these resources one must do it through some form of sharing; in many cases networks provide the most economical means of sharing.

One of the very important benefits from networking will be the fostering of person-to-person communications and the strengthening of so-called "invisible colleges" — informal networks of people working on collaborative projects. That type of benefit simply cannot be gained through other than relatively advanced communication technology.

We are beginning to get some of the benefits of networking, but we are certainly a long way from their full realization. There are still technical, economic, and administrative problems that we must face. I would first like to talk about some of these issues, and then discuss what I see in the future for networking.

TECHNICAL ISSUES

First of all, let me say a little bit about technical issues. We tend to dismiss technical issues, and for the most part this is probably justified. Despite the fact that tremendous technical advances have been made, however, we still have some technical problems that are going to plague us for the foreseeable future.

For a number of reasons, the network that EDUCOM is developing, called EDUNET, is based on a common carrier communication network; in particular, we think the public packet-switching networks offer very attractive capabilities. There are still technical problems with these networks, however. It is relatively expensive to interface to the network — that is, to provide a link from an institution to the nearest node of the common carrier network.

Ruth Davis and others have talked about the problems of providing security and assuring privacy. We see these as very great limitations on current networks. As a result of these weaknesses, most institutions will not make accessible through a network those data bases that are of a sensitive nature, such as student records or faculty salaries. Although in the long run it is important to reduce current limitations, for the time being they are not especially inhibiting, because the applications that deal with secure data are unlikely to be a very significant part of network traffic anyway, even if the security problem were solved.

One of the very serious technical problems that we face is the provision of user services over a network. There is a certain amount of person-to-person contact necessary to aid an uninitiated user in using a computer. In a university or college the problem is usually dealt with in relatively informal ways. There is a body of expertise within the campus on which a new user can rely: fellow students, faculty members, and sometimes student consultants. In a national network, that local body of knowledge will not be easily accessible to a potential user, and therefore we have to develop means to provide equivalent services over a network. One very important way of doing this is to provide certain on-line, computer-aided services — computer-assisted instruction, perhaps computer-assisted diagnostics, and on-line retrieval of directory information — so the user can locate a particular resource that he or she would like to access. Developing these automated aids presents serious technical problems.

ECONOMIC ISSUES

Let me now discuss the economic issues. An important phenomenon that must be recognized in talking about networking is the declining significance of hardware costs. The point has been reached where hardware costs are almost an insignificant part of the total cost of delivering computer services. Other costs — communications, mass storage, remote terminals, human design effort, administrative effort — overwhelm hardware costs. Therefore, networks are unlikely to reduce hardware costs very much; there's just not much left to be reduced. Most computing in higher education, as well as in the society as a whole, will be handled locally through intelligent terminals, because the cost of delivering intelligence from a local mini- or microcomputer will be very low indeed. The primary benefits of networks will come from access to data bases and software that have a high labor content and not a high hardware cost.

Over the last ten years there have been fairly strong pressures toward centralization, justified primarily on the grounds of economy of scale. One way to gain economy of scale is to generalize a computer center in order to accumulate more and more users who want to access its resources. That is, the center offers a wider variety of resources in order to accumulate a larger user population. This strategy clearly carries a cost. There are costs of developing and maintaining very complex, generalized software. There are certain overhead costs incurred by the operating system in allocating generalized resources to individual users. There are added user-training and consulting costs necessary to assist users in accessing a particular resource out of the wide variety of services available. And finally, inconvenience and lack of hospitality are always lurking problems in large computer centers.

Specialization eliminates many of those problems of generality. One of the great advantages of a network is that it allows specialization while still exploiting economies of scale. Computer centers that offer a specialized service can often attract enough users through a national network to justify the high fixed costs of maintaining the service. Networks can thus complement localized centers. The typical computer center may choose to provide relatively standard services for its own users, plus a few specialized services for the national market. It will then look to the network to obtain specialized services that it does not provide.

Communication costs are, of course, an important economic issue. It is likely that the public packet-switching networks will play an important role in resource sharing. If one is in the fortunate position of being in a high density area communicating with another high density area, the cost of communication for interactive computing is quite acceptable for most applications and most users — perhaps on the order of $2.00 per hour. As one gets outside of the high density areas, however, the costs start going up fairly steeply. The cost of linking a local terminal to the nearest network node becomes a crucial component of total cost if the network node is outside the user's local calling area. The economics of the packet-switching network thus change very rapidly as one gets away from the dense areas. This is particularly a problem when one gets into applications that involve a high volume of data transmission. Because of this, relatively low-volume applications — such as interactive computing — are likely to constitute most of the network traffic over the next few years.

The economics of user services is a particularly important issue for a national network. A carefully debugged and documented program is expensive to provide. In many cases, universities do not offer software of commercial quality. This is simply not acceptable in a national network.

It is not at all unusual for a commercial data center to spend 25 percent of its gross revenue on the delivery of various types of user services. Most universities do not spend anything like this; an expenditure of 10 percent or less is not uncommon. Thus in considering the economics of network services, universities are going to have to decide whether they are willing to assume the added cost of providing higher quality software and higher quality user services.

The economics of networking certainly have to take into account the cost of the overhead associated with any sort of sharing. In going from a local resource to a nationally shared resource, there are inherent costs in marketing the resource, handling the billing, controlling expenditures, and so on. Because of these added costs, there has to be good reason to use a network instead of a local computer center. For this reason most network traffic will be limited to sharing scarce resources.

ADMINISTRATIVE ISSUES

Let me get into the third major problem area, the administrative issues associated with developing a network. There are a number of administrative questions that must be considered, such as how the network should govern itself, how incentives can be provided to encourage sharing, how resources should be priced, how institutions should budget for network purchases, and how to deal with some difficult legal and regulatory problems. Colleges and universities are autonomous, and they have no desire whatsoever to relinquish that autonomy in the alleged search for economies in computation. Accordingly, the development of EDUNET is based on the assumption that an institution's use or nonuse of a network will be based solely on its own self-interest. Thus we're relying heavily on a free market mechanism to provide incentives to use a network where it's appropriate. There are certain facilitating services that we think should be centralized — such as billing and reporting of computer use, contracting with communication vendors and perhaps other vendors, and providing user services so that a remote user can locate a particular resource. These are, by their very nature, centralized or coordinating activities, and so they will probably have to be done through a central organization. But except for these facilitating functions, the autonomy of network members will be preserved.

The incentive question is a central issue in the design of a network for higher education. The slow growth of networks stems in large part from the poor incentives that currently exist. The creators of software and data bases typically have meager incentives to spend the extra effort to develop high quality software and documentation — chiefly due to the lack of an established market. Supplying institutions have disincentives in many cases to join a network. There are certain financial and legal risks associated with serving remote users. Service to network users may also cause disruptions to the local community, and may be resented by faculty and students even though resource sharing may be in the best interests of the institution as a whole. Individual users also lack incentives to use remote resources because of the relatively poor quality of most software and support services. Users often experience tremendous frustration and inconvenience in using a remote resource. Institutions that buy from a network may find it more difficult to pay for external purchases than to support the continuing costs of their own computer centers. Thus, lack of incentives on the part of creators and users of computing services, as well as buying and selling institutions, inhibits network traffic. Except in cases in which sharing offers the only way of accessing a unique resource, it is usually easier simply to develop one's own resources and execute programs locally.

A national network, once developed, offers hope of changing the incentive structure. The incentive for the supplier will be much greater than it is now, because the institution can obtain funds from external sales that it can then use for the purchase of computing resources from others. This motivates suppliers to improve the quality of their services, which in turn increases the incentives for users to look at the network for specialized resources. Unfortunately, we face a chicken and egg situation: until the network reaches a reasonable size, or has at least the expectation of reaching that size, suppliers will be reluctant to spend the funds to develop high quality software.

Pricing is another crucial administrative issue. There's a lot we don't know about the effect of a free market mechanism on the distribution of computing resources, and there's a lot we don't know about the effect of different pricing schemes. We don't know, for example, whether prices in a network will be stable or not. One could hypothesize either alternative: intense competition with prices varying almost daily in response to changes in supply and demand, or, on the other hand, relatively stable prices because administrators see wildly fluctuating prices as being dysfunctional to their own users and their own institutions. EDUCOM is currently engaged in a large project funded by NSF to investigate some of these matters.

One of the most serious questions we have to face is just how prices will be established. What will be the need for non-market mechanisms such as price regulation, quotas, tariffs? What price structures will evolve? Some institutions will probably follow the common practice of offering only "spot" prices, where they simply charge on a per-job basis. In other cases institutions may want to enter into long-term contracts with buyers or the facilitating organization. If prices are to serve as a resource-rationing mechanism, they should recognize the economies of different qualities of service. A user wanting high-priority or peak-period service should therefore pay a premium for it, because that leads to a more balanced utilization of the network and lower prices for those willing to accept lower priority or off-peak services.

In certain cases it may be attractive for an institution to offer access to a limited type of service, like time-sharing BASIC, for a fixed monthly charge rather than on a per-job basis. This makes considerable economic sense, because the cost to the supplier is essentially fixed for a given capacity level, and therefore this pricing scheme simply transfers the fixed cost to the customer. Resources offered under these terms are generally limited by non-price means, such as size of core or number of CPU seconds, in order to avoid excessive usage of available capacity.

The issue of pricing is, of course, different from the question of who bears the cost of computing. The use of prices to ration resources would certainly not preclude offering subsidies to certain classes of users or applications. Thus, the advantages of network computing could be provided through appropriate subsidy to users who otherwise could not pay for it, if an institution felt that this was an appropriate expenditure of its funds.

I can only hint at some of the legal and regulatory issues that we have to face in developing a national network. It is by no means a resolved question whether a nonprofit educational institution can freely sell computing services and still retain its nonprofit status. There is also the question of constraints imposed on pricing flexibility by government contract regulations. The federal government requires that it receive the most favorable price offered to any buyer, which constrains the ability of an institution to use flexible prices in rationing its resource more efficiently. Many computer centers at universities must compete with government computer centers that charge less than full cost for services rendered to academic researchers. If a network relies on a market mechanism, having one group of suppliers subsidized by the government may seriously distort the efficient allocation of resources.

FUTURE BENEFITS OF NETWORKING

Although we face some formidable problems in developing a national computing network, the long-term prospects are encouraging. We expect growth in network traffic to be steady but not dramatic. There are a number of things that must take place before growth can occur: users have to become familiar with resources located elsewhere, supplying institutions have to gear up to meet the special requirements of remote users, and facilitating services have to mature.

Once the network is more fully developed, universities and colleges will have to consider a variety of alternative sources of computing. One alternative, of course, is to simply ignore the network. At the other extreme, some institutions may decide to become totally dependent on the network. This may be a reasonable alternative for smaller colleges that have no special interest in running their own computer centers, but it is unlikely to be attractive for larger institutions. Most institutions will probably follow a hybrid policy. An institution will supply standard base-load services to its own local users; these services can be provided very cheaply with a stable conventional computer or a minicomputer. A larger institution will probably also choose to specialize in certain applications in which it has a comparative advantage because of its research or teaching competence. In addition to supplying these specialized services to its own local users, it will also sell the services on the network. With the funds generated, the institution will then be able to buy other specialized services that it does not maintain itself. I suspect that many large institutions will try to end up with a relatively small net balance of trade. The total trade might be very substantial, but the net trade — the difference between what an institution buys and what it sells — might be kept to a fairly small figure.

The network that evolves will be highly decentralized and functionally distributed. A national network is likely to be a very fluid free market, offering a large variety of services. Economics will favor local or regional computing for most services, with the national network focused on specialized services that cannot be economically maintained locally.

Person-to-person communications is likely to be one of the more important services available from a national network. "Electronic mail" is generally regarded as the most valuable service offered to researchers on the ARPA network, the original packet-switching network. This came as a surprise, but in retrospect it seems entirely reasonable. A network provides a capability of linking people that no other communications medium can match. The telephone is very effective for interactive discussions, but it does not offer many of the functional capabilities that can be made available through an electronic mail system — such as the ability to broadcast to a number of people simultaneously, to store messages for later delivery on demand, and to retrieve selected information from past messages. It might be attractive to maintain interest profiles of persons who wish to communicate with others — an automated pen-pal arrangement, if you will. Such a capability could enormously enhance the value of the informal "invisible colleges" through which professional workers receive much of their knowledge of current developments within their field. There is strong evidence that most researchers tend to get information from other people rather than through the formal literature. Electronic mail systems and "invisible college" links can tremendously amplify these very powerful sources of information.

Networks will play a vital role in providing library and bibliographic services, such as on-line bibliographic retrieval. They will also allow access to so-called "electronic handbooks" in order to retrieve factual information, such as the physical or chemical characteristics of materials. Networks open up the possibility of electronic publishing, in which publishers assemble material and make it accessible over a network rather than in conventional hard-copy form. In short, networks will provide a worldwide marketplace of ideas that simply could not be disseminated by other means.

The powerful technologies of computers and communication networks can certainly be abused, and we have ample evidence that people do abuse such technologies. On the other hand, we also have evidence that with suitable care computer services *can* be made humane, error tolerant, adaptive, and

James C. Emery

responsive. Networks, acting through the free play of a market mechanism, are going to offer a very important means of making such services more widely available.

Dr. Emery is President of EDUCOM, a nonprofit consortium of colleges and universities, and is involved with the design and implementation of a communications network to link the computer centers of U.S. colleges and universities to permit the sharing of computer hardware, software and data bases. He received a B.S. degree from the University of Arkansas and his M.S. and Ph.D. from M.I.T., and was also a Fulbright Scholar at the University of London. He has taught at M.I.T. and the University of Pennsylvania.

AGREE
Adult Youth
71% 62%
DISAGREE
Adult Youth
15% 14%

ABSTRACT

The results of a survey of public attitudes towards computers in society recently completed by *Creative Computing* magazine will be described, as well as a discussion of new technologies. What new games and recreations will computers bring to the home? Will the artist or author be assisted by the computer, or frustrated by it? What overlap is there between commercial applications in banks, business and government, and personal applications? This presentation will probably raise more questions than it provides answers.

Computer Power to the People

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We all know that computers are around us; they're invading our lives along dozens of dimensions. We see them in supermarkets: the little product code that you find on the side of virtually every food and grocery product you buy can be read by an optical scanner connected to a computer. Computers in department stores: a little "magic" wand, actually a tiny laser device, reads a product code from the tag. Medical facilities: hospitals frequently keep all their patient records on computers. When you're admitted you often undergo some kind of questioning process. One psychiatric hospital out in Utah takes the entire patient history, and in fact, does the preliminary diagnosis of all entering patients by means of an on-line computer program. College admissions: for instance Fort Lauderdale Community College, and hundreds of others use on-line computers. Every time you pick up the telephone and dial it you're actually using the largest general-purpose computer in the world, the switched telephone network. Magnetic ink character recognition in the bank; sports stadium score boards; and so on.

My premise is that now, some 30 years or so after the invention of the computer, it's having a tremendous impact on our lives. It is having an impact on our lives similar to what the printing press did, but instead of taking some 400 years to make its effect known, the computer is having a vast effect in something like 20 or 30 years. We just can't escape it.

So some 30 years after the invention of the computer we decided it would be a nice idea to find out what people think about computers. Do they view it as a master, a slave, a dictator, a monster — in fact, do people really understand what the computer is all about and what it's good for? We took a survey among both adults and young people with 17 different questions. We posed statements and asked them, "Do you agree with this statement or disagree?," and got their responses. We also had some open-ended questions, and we continue to ask people open-ended questions like, "If you had a computer in your home, what would you do with it?"

David H. Ahl

THE MYTH

First of all we asked some questions about what you might call the quality of life. Did people feel that the computer was going to improve various facets of society? Well, for the most part, there was pretty good agreement that computers would improve education somehow; a very substantial agreement that computers would improve law enforcement; a little less agreement, particularly among younger people, that computers would improve health care; and some agreement that computers are worthwhile for prevention of fraud through credit rating data. This last one is interesting. This question was asked in the AFIPS/Time Magazine survey just four years before our survey; the percentage of people who felt credit checking was a good application dropped from 74% to 64%, so 10% more people today have some doubts in contrast to four years ago. I guess in four years many people have been stung in one way or another by credit ratings or other foul-ups.

We asked some questions about the threatening nature of computers: "Do you feel you can escape the influence of computers?" People for the most part felt that they couldn't; a surprising number of young people felt they could. (I'm not quite sure where they were going to go to do it, certainly not the United States.) There was some feeling, particularly pronounced among West Coast respondents, that the computer could influence the outcome of elections. Senator John Tunney of California was one of the biggest critics of the use of computers to forecast the outcome of elections. Senator Tunney, if you'll recall, was defeated in November 1976. I'm not sure if computer projections had anything to do with his defeat, but, in fact, his fear was that by the time the voters went to the polls in the Western states the major national election was locked up. In 1976 it wasn't quite locked up by the time they went to the polls, but frequently it is — and therefore people may say "Why bother?" or "Gee, there's a bandwagon; I want to get on it and vote for the winner." Or, "I was going to vote for the other guy, and he has lost, so I can't be bothered going to the polls." That may not affect the outcome of the national elections, but it has a tremendous effect on the outcome of local elections and local bond issues. So, John Tunney at least was pretty upset about using computers in the forecasting of election results.

"Computers dehumanize society by treating everyone as a number." On that statement we had some ambivalence: some people agree, some people disagree; certainly a substantial number of people are a little bit fearful and do feel the computer is dehumanizing things by treating them as a number.

We asked five questions to get at whether people understand the role of a computer. Do they really know what it's good for, and do they know its applications? One of those statements was, "Computers are best suited for doing monotonous, repetitive tasks." Well, 80% of the adults agreed with that, although only 67% of the young people did, which gives rise to the hope that young people can see that computers are good for doing more than just dull, repetitive tasks. Are computers a tool? Yes: a pretty substantial agreement that they are a tool. I think that's a good thing. But I think it matters a lot whether people view it as an intellectual tool, or whether they are thinking of it as a plain, ordinary tool such as a hammer, for example.

"Do computers slow down and complicate simple business operations?" Some people felt that they did, I'm not quite sure who. There's a substantial agreement that computers are going to replace a lot of jobs and create jobs that need specialized training, and some people really fear that they might not be qualified for the jobs that will exist after the "computer revolution." Also on the jobs issue we asked whether people feel that computers will create as many jobs as they eliminate. About two-thirds agree, but that leaves a fair number who disagree. You have to remember that people have always been fearful of any kind of industrialization or technological breakthrough. The Luddites were anti-technology; to them the industrial revolution meant the machines were going to take all the jobs. Well, it just didn't quite work out that way, and I don't really think computers are going to take all the jobs either.

Then we asked a couple of questions to see if people really understand the computer itself. We first asked, "Are computers beyond the understanding of a typical person?" The response was mixed; at least a quarter of the people think that computers are beyond their understanding, but I'm encouraged by the larger percentage of people who disagree. "Computers make mistakes at least 10% of the time." You have to feel sorry for the 10% of the people who do think that computers make mistakes this often. In fact it is the programmers and operators who make the mistakes and not the computers. But in these questions we gleaned a little bit of intelligence that somewhere between 13 and 19% of the people just actually don't know what's happening, don't know what computers are all about, and don't know who's running them. They think the computers are

	ADULT (N=300)		YOUTH (N=543)	
	Strongly or Mostly Agree	Strongly or Mostly Disagree	Strongly or Mostly Agree	Strongly or Mostly Disagree
Computer Impact on the Quality of Life				
• Computers will improve education.	86.6%	5.9%	84.2%	4.5%
• Computers will improve law enforcement.	81.9	3.3	70.0	10.1
• Computers will improve health care.	78.6	5.3	54.1	11.9
• Credit rating data banks are a worthwhile use of computers.	64.2	13.4	64.0	7.6
Computer Threat to Society				
• A person today cannot escape the influence of computers.	91.6	4.0	66.6	17.7
• Computer polls and predictions influence the outcome of elections.	48.1	27.5	44.2	26.9
• Computers dehumanize society by treating everyone as a number.	37.4	50.3	39.9	30.6
• Computers isolate people by preventing normal social interactions among users.	18.7	62.5	20.9	42.5
Understanding the Role of Computers				
• Computers are best suited for doing repetitive, monotonous tasks.	80.0	10.3	57.0	21.6
• Computers are a tool just like a hammer or lathe.	72.6	14.7	61.3	23.4
• Computers slow down and complicate simple business operations.	17.6	66.4	17.4	68.8
• Computers will replace low-skill jobs and create jobs needing specialized training.	71.0	15.0	61.8	14.4
• Computers will create as many jobs as they eliminate.	62.5	16.4	40.0	29.1
Understanding of Computers				
• Computers are beyond the understanding of the typical person.	25.2	61.6	30.6	49.2
• Computers make mistakes at least 10% of the time.	9.6	76.7	10.3	60.0
• Programmers and operators make mistakes, but computers are, for the most part, error free.	67.0	19.3	72.3	13.3
• It is possible to design computer systems which protect the privacy of data.	60.2	26.4	48.6	15.9

FIGURE 1

Statistical Results of Survey of Public Attitudes Towards Computers in Society running the people rather than the other way around. A substantial number of people just didn't know, which is also upsetting. So, there's a good portion of our society — at least a third or so — that just doesn't know some of the fundamental issues and facts about computers. We asked one last question, "Is it possible to design computer systems to protect the privacy of data?" Well, not even the computer designers know for sure, so I don't think we could expect much from people that we asked.

So all in all, we have some ambivalence; people are optimistic on some counts, pessimistic on others, and some things they just don't know. The ignorance is probably most apparent when you ask someone what he would do if he had a computer at home: "A computer? What do you mean a computer? You mean like a hand calculator?" Some people thought we meant robots. "Well, maybe I'll have it serve me martinis when I come home from work." They just couldn't quite visualize a computer at home. A computer is supposed to be something that goes behind glass doors and is on raised flooring and requires a lot of electricity. "I don't have the kind of home that would suit a computer," said one.

I guess this mixture of attitudes really shouldn't be too surprising. The everyday perceptions of a computer are formed by people in the media — newspapers, comic strips, TV and elsewhere — people who really don't know what computers are all about either. For example, what does a newspaper cover? They're going to report the computer error, the problem with the computer. How many of you read a couple of months ago about the Shop-Rite in Springfield, New Jersey, with a brand new laser scanning system at the checkout? This was the grand opening day, and they really crammed the people in. They had hundreds of people all filling their carts with these grand opening specials. People were lined up at the cash registers with two and three carts each laden with groceries. They were seven or eight deep at every cash register, and all of a sudden, bang, the system went down. Not only did it go down, but it locked all the cash drawers. So there was no way of making change. They couldn't use the cash registers manually. There was just no way of opening them up. Rumors started flying around. People said, "The cash drawers are locked, the doors are going to lock too; we're going to be locked in here forever." And then there was a rumor that a replacement computer was going to have to be shipped in from Texas and they'd have to wait until it arrived! It was wild. Finally the manager decided that the best course of action was to give each checker a pencil and some brown paper bags which were at the check-out position, and have them add up manually the groceries in these laden carts. People were there for literally hours. The interesting thing is they did not lock the doors, and more people kept streaming in. They didn't want to lock the doors because of this panicky rumor inside the store, "If they lock the doors we might be stuck here." They didn't want to start a riot. The newspapers had a field day with the story.

Most of you have heard about the frivolity out in southern California when McDonald's had a sweepstakes. To enter, all that was required was a 3 x 5 entry form or facsimile; in other words, you could write the entry on a 3 x 5 card of your own. Students at one fraternity programmed the computer to produce entry forms, 1.2 million of them, and then they stuffed every ballot box of McDonald's in southern California. They won 90% of the prizes in the contest. McDonald's was very upset about it. They said it was anti-American. I think it was very American; it showed a lot of ingenuity and creativity. In fact, McDonald's awarded duplicate prizes to people who were not members of this conspiracy to defraud them. The winning fraternity invited Ronald McDonald to make the prize presentations over at their fraternity house at dinner, but he declined the invitation. Actually, Burger King got the best publicity out of this. They gave a $3,000 scholarship to the university in memory of the prank. Again, the newspapers had a wonderful time blaming the whole thing on a computer.

A college student at the University of Arizona insured the life of his guppy. He put down all the correct information on the mail order insurance form: height 3 centimeters, weight 30 centigrams and so on. It died of course, as most guppies do, some four or five months later. He submitted a claim for $5,000, which was what he had insured it for. The insurance company said it was an invalid claim; the computer had made a mistake by accepting the party. Well, the computer hadn't made a mistake; it was a programmer who hadn't allowed for somebody who was 3 centimeters high. It wasn't the computer. But the newspaper, how did they portray it? Sure, another computer error.

In Swansea, Wales, a young man of 17 applied for a driver's license and passed his test shortly after. But when his license arrived, it bore 12 endorsements for a whole array of driving offenses, plus a 28-day driving suspension. Police proved sympathetic when it was found that "the computer at the license office had run wild. The system has not been operating for long," said an official.

There was a cute little notice printed recently in the *Chicago Tribune*. "A COMPUTERIZED bill had this notice on the bottom: Failure to receive this bill is no excuse for non-payment of the amount shown." Why capitalize "computerized"? Does that mean the computer printed that notice on the bottom of the bill? As if the computer could have made that up out of the blue sky. The computer is the scapegoat for the Post Office now. That's what's really happening!

A woman in Shreveport, Louisiana, got a gas bill for $42,474.58. A customer representative at Arkla Gas Co. stated, "The computer went haywire and some of those bills got out." Computer error? Hardly. Good for the newspaper? You bet!

Movies are another way that people form perceptions of the computer. For example, in *2001*, remember when Commander Bowman finally gains access to the memory banks after Hal has been harrassing him for half the trip, and he yanks out the circuits one at a time? Finally Hal breaks down as Bowman performs the first successful interplanetary lobotomy. Or have you seen the movie *Colossus*? Colossus "wakes up" and gains sentience very much as the computer did in Heinlein's book, *The Moon Is a Harsh Mistress*. Well, Colossus gains it while it's hooked up to its Russian counterpart. The computers are in charge of the National Defense Systems of both countries, and the two computers decide between them that it would be kind of neat if they held the population of both of their countries hostage. A movie that will be coming out shortly called *Demon Seed* has a computer in it, Proteus IV (appropriately named), equipped with an ominous blue arm enforcer with which the computer keeps people in the movie hostage, mainly Julie Christie (that probably makes it worth seeing even if you don't like computers). Three movies and three impressions of computers — all false.

Some people get their images of computers from books (not too many, because not too many people bother to read books anymore). Science fiction writers are probably the one group of writers in the country that is portraying future computer uses reasonably realistically and making some half-decent speculations. Unfortunately, very few people read science fiction, so we don't have to worry about many people getting a realistic view of computers from that source.

So, consequently we know a little bit from the survey about what people think about computers, and a little bit of how these impressions were formed from my rather incomplete discussion of it, but I think you can fill out the missing pieces. We know, too, that if we ask the average person, "What would you do if you had access to a computer or if you had a computer in your home?," he really doesn't have a very good idea. In fact neither do many professionals or manufacturers. The fact is that we're really not very good at forecasting the future. We really can't and never have forecasted future technological innovation or invention very well.

Back around the turn of the century, who would have forecasted life today as it actually is? In those days the best guess of what the Panama Canal would be was a railroad pulling ships across the isthmus. Back in those days it probably seemed reasonable. I'm sure if the Wright brothers had asked the drivers of ox carts what they would do with an airplane they probably couldn't have given them a very good idea. Henry David Thoreau, one of our leading philosophers, commented when he was told that the telephone would permit people in Maine to talk to people in Texas, "But what does a man in Maine have to say to a man in Texas?"

THE REALITY

It's pretty clear that we can't forecast 70 or 50 or probably even 30 years very well, particularly with a high-technology item such as a computer. So let's just look 5 to 10 years into the future. Even so,

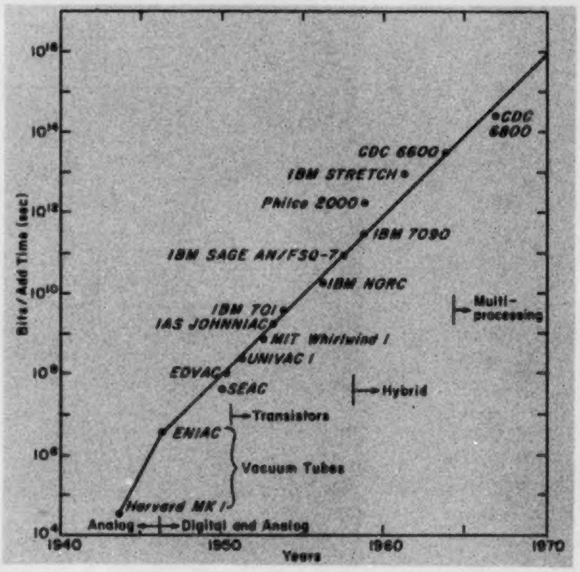

FIGURE 2

DIGITAL CAPACITY AND COMPUTING SPEED

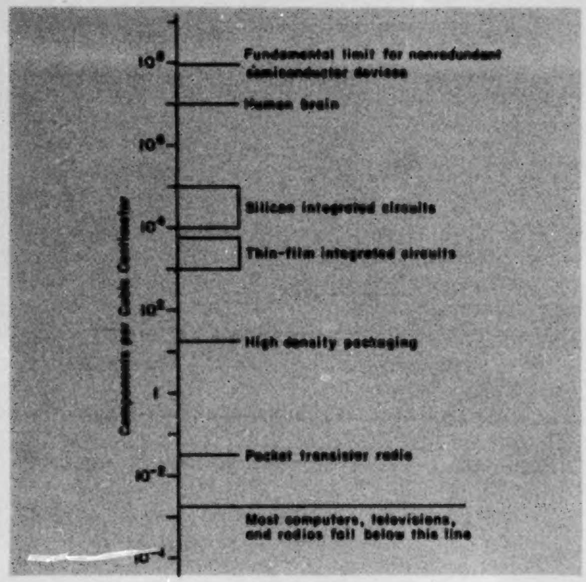

FIGURE 3

Packing Densities of Microelectronic Systems

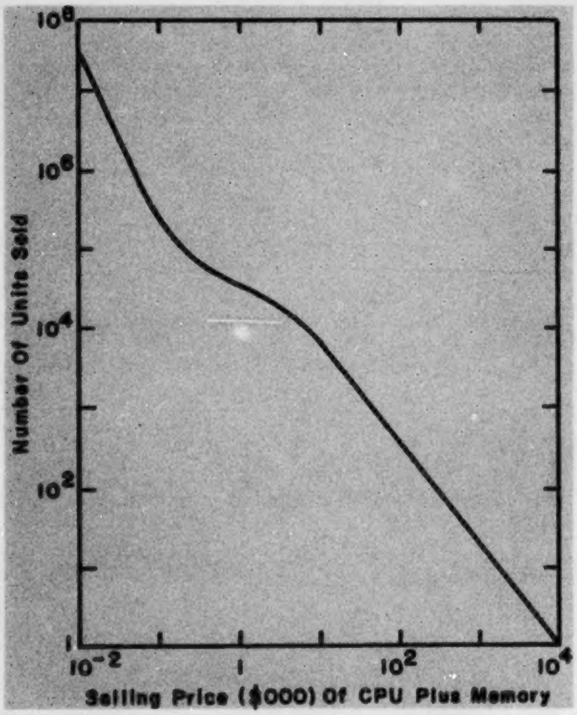

FIGURE 5

Price of Central Processor Plus Memory

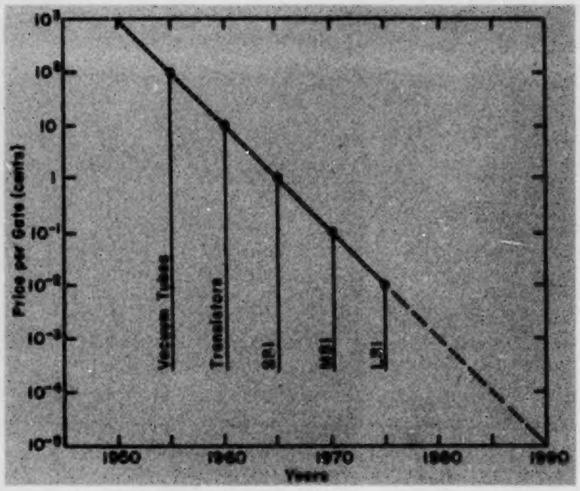

FIGURE 4

The Cost of Logic Gates

we can't foresee exactly when everything is going to occur. We would certainly expect that processor instruction speed would continue to increase very rapidly. Packing density will also continue to increase dramatically. Currently, we are within two orders of magnitude of the human brain. Actually, the theoretical limit for semiconductor devices is packed more densely than the human brain. Currently, bubble memory circuits in Bell Laboratories about 1 centimeter square will store about 1.5 million bits.

Coupled with miniaturization, prices are rapidly falling. Let me tell you that more than one manufacturer is a little bit alarmed at the projection of hardware prices approaching zero. The indication is that as the prices come down the number of units sold goes up very dramatically. This applies not only to calculators but to computers as well. What happens as prices come down? What do you think the value of this ratio is today?

$$\frac{\text{Cost to program 1 line of code}}{\text{Cost to execute 1 line of code}}$$

One hundred to one? A thousand to one? Ten thousand to one? Wrong. IBM says the ratio is 100 million to one, and that was two years ago! Given the current increases in processor speed, it's probably a lot more than that today. What that indicates, of course, is that the human element is by far and away the most important thing in computers and technology today, in making them all work.

So what does it mean when you put all this technology together? Well, obviously it means smaller terminals, terminals that fit in your pocket. Sophisticated and very small color video cameras. Calculators with as much power as a computer of 20 years ago. Hobbyist computer kits that are within the price range of a quarter of the households in the U.S. (Close to 30,000 hobbyist computer kits have been sold as of the end of 1976.) Technology means people talking to other computers and terminals by means of the telephone network, using standard teletype terminals or new high-speed terminals or plasma panels that are built into the phone. A panel that can be written on with a light pen or typed on; or can display information from a computer, data bank, directory, or from local storage.

Today there are over 100 manufacturers of personal computers and peripherals. At *Creative Computing* we can't possibly keep up with all the new product announcements for new hobbyist computer kits and peripherals. We started a new product section in early 1975, and the hardware portion was about one page. In the January-February, 1977, issue we ran 9 pages of closely spaced descriptions of new hardware. It's a revolution. Two hundred computer stores are open now, and a new one is opening every four days: retail computer stores where you can go in and buy yourself a microprocessor, a computer kit, or peripherals.

Extensible, user-defined, simple languages are being developed. Harvard has a new language called ECL. It's not like today's simple language, say BASIC or LOGO. ECL doesn't use constructs that have to be absorbed into your intuition, but rather you use concepts that are already part of your intuition, part of your language, and then you construct the computer language out of that. Whether you're a banker, a baker or a professional programmer, you can produce a computer language that does exactly what you want.

Out at Xerox' Palo Alto Research Center they've got a thing called the "Dynabook." The original idea was that Dynabook should in every way be better than a book. It can display printed pages on its screen: black on white, white on black, red on green, etc. It can display pages in any style and size typeface. If you have some visual problems and you want a page in large type, it displays it in large type. For reference material it can use very small type. Not only can you read things but you can write things on it. You can just draw a circle around a word and show where you want it moved with a little arrow, and the computer moves it for you. You can edit your material from a keyboard if you'd rather. You can strike over lines and they disappear. The next time you push a button you get all your text nicely justified on the screen. Actually, it's better than a book in every way because you read it, you can write it, you can change it. It's also better in the graphical sense. It would be nice if the illustrations in a book could move (kids love little pop-up picture books). The illustrations on Dynabook can move with full animation. In fact not only can they move the way that they're programmed to move, but if you'd like them to move in some special way, you simply take your light pen and draw over the illustration and let the computer sequence through your frames. This is reality. This is here today. It's not quite the size of a book today — it's about the size of 3 bread boxes — but it's not going to be too long before it is the size of a book. In addition to having book qualities, it's also a general-purpose computer with the ability to do parallel processing on eight different levels. When you think of it, that's the way human beings think. When I'm walking along, for example, one part of my brain is thinking about putting one foot in front of the other, another part is thinking, "It's cold out. I'll be glad when I can get inside." Another part is thinking about the speech I'm going to give tonight, another part is thinking about the person I'm talking to, and still another is thinking about the beer that I'll have later on, and so on. So your brain is processing information on a parallel basis all the time. Well, wouldn't it be nice if you could have a computer that could do that, too, and have the output of one level serve as the input to another? That's precisely what Dynabook provides. It's a phenomenal machine. I'd like to think that within 10 years it will be as commonplace as the pocket calculator is today.

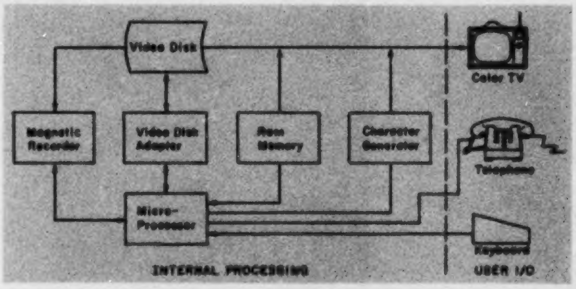

FIGURE 6

FUTURE HOME COMPUTER SYSTEM

David H. Ahl

I feel one of the keys for getting computers into the home is the widespread availability of cheap, high-quality software. One possible vehicle for bringing this about is the video disc. Quite inadvertently, a stroke of luck perhaps, the storage technique employed by the disc is binary, or digital, just what's needed for a computer. So while the player will be brought into the home for entertainment, its real power lies in the fact that if you couple the video-disc system with a microprocessor and keyboard you have an incredibly powerful audio-visual-computational-educational-recreational device. One video disc can store 10^{11} bits of information, the entire *Encyclopedia Britannica* for example, or a very comprehensive software library. You could have Jackie Stewart introducing the Monaco Grand Prix, taking you on a prerecorded ride around the circuit, and then turning the controls over to you. Or Kirk handing you the controls of the *Enterprise* just as the Klingons are about to attack. Or Fran Tarkenton coming off the field and putting you in as quarterback in the Super Bowl.

THE CHALLENGE

There's no question that in 5 to 10 years solid-state and related technology are going to put some fantastic things well within the reach of everyone who wants them. It's equally clear that most people have little idea of what they'd do with a computer if they had one. Hence, we have quite a chasm between the insiders — those who have learned about computers from school, work, or hobby — and the outsiders, who don't know much about computers and don't really care (today).

It would be nice to think that this chasm could be bridged by education (like the new math or metric system?), but it's not likely that schools will really face up to computers until every kid has his own (pocket calculators all over again). Business and industry are wedded to large EDP systems, with most DP Managers pretending that microcomputers are just toys, hence we can't expect any help from that quarter. Most likely it will be the people, plain ordinary folks, who see a friend with a computer and decide to get one of their own. And as this increasingly happens, we're going to have the most massive domino effect you ever saw — calculators and CB move over — you ain't seen nothin' yet. Computer power to the people is on the way!

Mr. Ahl is Marketing Manager – Education, for AT&T; by avocation he publishes Creative Computing *magazine. Prior to joining AT&T he was Education Product Line Manager for Digital Equipment Corporation and a consultant with Management Science Associates. He has written numerous books, instructional materials and papers about the use of computers in education. He received a B.A. from Cornell University and an M.S. from Carnegie-Mellon University.*

ABSTRACT

The confluence of modern-day computer technology and an ever increasing demand for information by societal institutions has created a circumstance in which it is becoming clear that public policy will have to be established to control the collection and use of some kinds of information. The contemporary social issue of privacy is the first instance in which the problem has been dealt with in a broad omnibus fashion. This presentation will discuss the origins and background of the matter and suggest possible future areas of concern.

Public Policy Aspects for an Information Age

WILLIS H. WARE
The Rand Corporation
Santa Monica, CA

This occasion is one of special pleasure for me. At one time I had considered coming to Dartmouth for graduate school, and while I did not, at long last I have an opportunity to see what I missed. Another reason is what I might call the "Kemeny Connection." I was privileged to be part of John von Neumann's group at the Institute for Advanced Study building his machine; John Kemeny was also there as Albert Einstein's personal assistant. From time to time we would see John Kemeny at the Project; he also made a few pertinent remarks about a doctoral dissertation that I was trying to get finished. At the time there was no indication that the computer bug was biting him, but evidently the early exposure to it must have had some effect. Look what he caused to happen here at Dartmouth: look at what he has caused to take place with the computer as an educational tool, as a research tool, as an administrative tool, and as a record keeper. It is very proper that he should have made such events happen.

I did not attend the dedication of the Kiewit Computation Center ten years ago, but I can imagine the tone at the time was "Gee whiz, look what computing is going to do for us here." If we were to characterize this symposium, I think it would be "Holy smokes, look what it has done to us." Look what the computer has done to us in terms of funding support required; look what it has done to us organizationally; look what it has done to us by providing new ways to do old things; look at the relocation of power that has taken place. With such a lament over the past however, there must also be an anticipation of the future; the best is yet to come.

Willis H. Ware

ORIGINS AND BACKGROUND

Computer technology has paralleled what must be an inevitable course for any technology. There is an initial period of understanding and of finding it useful for things clearly good. Then there is a period of intense and perhaps wild exploitation; then a period of finding it being used in bad ways. Finally, the realization emerges that no technology stands alone, that it influences society and existing institutions, and that it interacts with concepts already in place. Of the many ways that a computer can be used, I will concentrate today on its role as a record keeper for information about people.

First, let me emphasize the staggering growth of computer technology. At its inception in the 1930's when mechanical computing began, operations were performed one or a few per second. Today, machines function at millions of operations per second. From 1 to a few million represents 6 to 7 factors of 10 in the growth in speed that has occurred. Estimates of future growth yet to come have been attempted; and with reasonable confidence, one can predict that there is another factor of 100 or perhaps another factor of 1000: that is, at least another 2 or 3 factors of 10 yet to go. By the magic year 2000, computer technology will have advanced by a factor of 9 or 10 factors of 10 — 10^9 or 10^{10}, which is a huge number. There are corresponding growth factors in other dimensions, such as size. By contrast, a technology that each of us experiences daily, transportation, has progressed from walking to the supersonic jets by a factor of only a thousand. Even if one envisions orbital transportation, it is only a factor of 10,000 — from about 2 miles per hour to 20,000. We readily appreciate the impact that transportation technology has had on each of us as individuals. One goes to London and back the same day for a few-hour business meeting; one has meetings like this anywhere, with people from everywhere. Transportation has made society mobile, and created all the supporting services that go with mobility. We even have a new phenomenon — jet lag — with implications for research on biorhythms. Understanding what transportation has done to us as a society and a country, we ought not be surprised that a technology like that of the computer, with its enormous growth relative to anything else, has had and will continue to have profound effects on society and its institutions.

Another line of argument is that we are a large country — a population over 200 million. Each of us leads a complex life. As a country we run large social programs, each of them having a requirement for accountability. We demand many services from government; social and private institutions are large. The sheer size of the country viewed as an organizational endeavor, its complexity and the growing need to keep costs in hand, implies a scale of record keeping that is unprecedented in history, record keeping that largely involves information about people. Our social insitutions, industrial, educational, governmental, have enormous needs today for information about people just to be able to function. On top of all that, information has been discovered for its own intrinsic value; it is now a marketable commodity. It can be bought, it can be sold and exchanged.

A third dimension of the argument relates to the situation surrounding use of information. An individual has no standing in law with regard to information about himself; he has no right of ownership. There are essentially no legal controls over the use of information, although there are occasionally controls over its misuse — libel and slander. Except for a very few instances, census data being one of them, there is no legal protection against seizure of personal information by judicial process. Thus, the intersection between information needs of modern society and computer technology set in a legally unconstrained environment has led to a situation in which vast amounts of information about people exist in record systems, both computerized and manual. The information circulates rather readily and is used freely by the record holder for the convenience, profit or efficiency of the organization. Collateral uses of information for purposes quite different from that of its original collection have sprung into use: the mail list is one of the less objectionable ones. Access to many record-keeping systems in the country is open to government agencies, sometimes for legally mandated purposes but often not. Computer-based record systems are playing major roles in determinations made about people, ones that involve rights, privileges, benefits, and opportunities.

The net result is a very one-sided situation with all the chips held by the record keeper. Obviously in such a circumstance, there can be manifold opportunities for abuse or misuse of information, and risks that individuals will suffer unwarranted harm. From these circumstances comes what today is commonly called the privacy problem. It is not a new problem; there has always been a need for information about people, and there has always been traffic in information about people. For example, we have been conducting a census in this country almost from the beginning. What is different today is the magnitude of record keeping — new kinds of record systems, record keeping by computer, new uses for information, new kinds of records. The computer has done what it so often does: it takes a long-standing chronic problem and makes it an acute one, in this case one of broad social concern.

THE PRIVACY ISSUE

In the context of record-keeping systems, privacy can be defined as the social expectation that an individual will (a) have some control over how, when and to whom information about himself is communicated; (b) have protection against unwarranted harm because of the functioning of some record system; and (c) have protection against unwelcome, unfair, or excessive collection of information. Such is the current privacy issue.

My present perception of the social goals that the privacy movement is serving are these. First, we are trying to assure that the public is well informed, collectively and individually, on record-keeping matters that affect people and influence citizens. An important goal is to raise the "information IQ", so to speak, of the public. Second, we are trying to strike a balance in the country between the genuine and well-founded needs of government and of private industry for information about people, and the right of those people to have some control over the use of information about themselves. We are searching for an appropriate balance point. Third, we are trying to assure fair use of personal information, especially when it is involved in making a determination about an individual. Fourth, we are trying to minimize unnecessary and intrusive information collection. The fifth goal is a very subtle one, not fully within the realm of privacy: we are trying to minimize the risk of inadvertently creating an all-encompassing set of record systems, each linked with the other, that make usurpation of power possible. I am persuaded that as a country we must minimize the risk that our record-keeping infrastructure will upset the balance of power in the present structure of government and society.

The genesis of record-keeping privacy as such was in the early 1970's with the books of Alan Westin, Arthur Miller, and James Rule. The subject came into very sharp focus when Secretary Richardson, then of the Department of Health, Education and Welfare, assembled a Special Advisory Committee on Automated Personal Data Systems. Its report, *Records, Computers and the Rights of Citizens*, was published in July 1973 and was a definitive treatment of the subject. It has strongly influenced nearly everything that has happened subsequently. The report was not only a comprehensive treatment of the subject, but it also made very important intellectual contributions. For example, it introduced the notion that the record keeper and the data subject both have an interest in seeing that information is used fairly. It introduced the notion that the situation should be governed through a code of Fair Information Practice. It even suggested what such a code might contain. One can recognize aspects of all these things in present legislation, and in the dialogue on the subject.

There have been numerous legislative attempts to address some aspect of privacy: the Fair Credit Reporting Act, the Fair Credit Billing Act, the Equal Opportunity Employment Act, and the Equal Opportunity Credit Act. Each of them is a rifle-shot approach targeting some specific information area. In contrast, the Privacy Act of 1974 is an omnibus approach that throws a broad umbrella of behavior and citizen privileges over federal record-keeping systems. The 1974 act also created the Privacy Protection Study Commission whose work is presently in progress. The Commission is scheduled to complete its task in June 1977, at which time it is obligated to make recommendations to Congress and to the President on the next step to protect privacy. High on our list of concern is the private sector, which at the moment is under no privacy legislation except for the few rifle-shot items mentioned. The Commission has held hearings on the major types of record-keeping systems, e.g., research/statistical, employment, personnel, medical insurance, depository, credit. We are currently in the phase of trying to understand what our data base is telling us, where the abuses are and what the remedies might be. It is one thing to conceive remedies, but quite another to balance them against the cost of implementing them. We will try to judge whether the remedies justify the cost.

While I can speak about the Book of Genesis for privacy, I cannot tell you much about its Book of Revelation. The Commission has not finished its job, and we have no preconceived notions of whether an omnibus approach or multiple rifle-shot approaches are appropriate.

NEED FOR PUBLIC POLICY ON INFORMATION

As we have worked through hearings and my understanding of the issue has deepened, it has become apparent that when we complete in June 1977, by no means will we have exhausted the subject. While the privacy issue will probably be taken care of under that particular name, there is another and much larger issue that I want to suggest; I think it is imminent and important. I have not yet found the precisely correct label for it, but it is something like "public policy on information." Let me speak to it by example. An obvious aspect of information is the right of ownership question. Do we need a legal standing for information about one's self? The problem has already surfaced as the country has re-examined its copyright laws, but it will surface in other dimensions. For example, under California law a hospital owns its records. My name is on such records and yet it is clear that a hospital does not own my name; I am obviously free to use it as I always have. One has to ask: What does ownership of information mean? Does it mean owning a particular representation of it as written on paper, or as recorded on magnetic tape, or as a pattern of voltages in a computer? Do we need to worry about ownership of parts of a record? Might I, the individual, have ownership over data about me that I have provided to a hospital, whereas the hospital owns the part of the record that it has constructed from whatever medical treatment it has performed? I do not know the answer, but obviously the question of ownership is going to face us one day soon.

A second example. An airline reservation system, an electronic bank terminal and a point-of-sale system all have an interesting and common characteristic: each captures information about some aspect of human behavior. One of them knows the whereabouts of individuals; another knows his buying preferences, or his financial habits, or his preferred charities. By inference, each contains a body of information with overtones of surveillance, but such systems were not created for surveillance. They were created to do a job; and to do it, each unavoidably captures information about people's habits. Nonetheless, there is created a body of information that is potentially exploitable for surveillance purposes, if someone is so inclined. Someone *will* be so inclined; it is likely to happen because people are not perfect. Someone will "discover" such a body of information and use or exploit it in ways that are quite tangential to the purpose for which it was collected. I suggest that we perhaps need a public policy for information of this kind to make certain that it does not fall into unintended and undesirable social usage. Perhaps we should pay especial attention to such bodies of information, as the Fair Credit Reporting Act has paid especial attention to credit reporting information.

A third possibility. When a physician treats a patient, he records two kinds of information. He records facts about health status, and laboratory findings; but he also records his own views, insights and conjectures. The two kinds are fundamentally different. One is very factual, but the other is conjectural, anecdotal, or episodic; it amounts to cues to himself. One kind of information, the factual, records the progress of a patient through medical treatment, whereas the other kind assists the physician in managing the progress of a patient through some course of treatment.

Educational records have the same characteristic. One part records the factual things about the student: grades, courses, honors. Another part, especially in the public school system, documents the anecdotal and behavioral notes put there by teachers or advisers with the intent of managing the student through his educational experience. Perhaps we will need public policy that deals differently with the two kinds of information.

A fourth example. There are increasingly many computer-controlled situations: traffic flow, air flight, power plants (especially nuclear), power grids, industrial processes such as oil refineries. Moreover, decisions formerly made by people are now being delegated to computers, to be made automatically. Quite aside from the safety aspects and quite aside from certifying systems, one wonders whether the liability laws of the nation are adequate for coming circumstances. Certainly one has to ask: Do we need to re-examine the liability laws when public safety is at risk? One cannot help but wonder about consequences to the insurance industry when it is asked to write a policy of huge face value against an event of very low probability of occurrence.

CONCLUSION

Put the picture together in a different way. Information is a universal commodity. It makes organizations run; it makes processes run; it makes each of us as a biological organism run. Computers deal in information in very general ways. Therefore, computer technology is becoming and will increasingly become all pervasive — a point that very few managements seem to understand. What has occurred in the last 25 years is minimal compared to what we have yet to see. I would find it as hard as anyone else to imagine what is ahead. Already there are computers in automobiles, washing machines and radar ranges. Simple computer-based games already exist; sophisticated entertainment and educational games are ahead.

There are already computer-based systems that play major roles in decisions about people. Computers influence our lives daily in very subtle and frequently invisible ways, and in that sense computer technology is being used to tighten the processes of society. Minimization of financial float in an electronic funds environment is one small and minor example. Others include being deterred by more complete information from exploiting record systems for one's self-interest, (e.g., multiple airline reservations) or being unable to lose a past identity and establish a new one.

As a country we may have to face the question: How tight will we allow our society to become through wholesale exploitation of computer technology for record keeping? Many record keeping applications are obviously socially desirable, and one would have no trouble with them, especially if they apprehend people who are skirting or breaking the law. A parent-locator system, for example, attempts to find defected parents and require them to assume the legal obligation to support children. A national driver registry attempts to catch the defrocked driver who, having lost his license in one state tries to get one in the neighboring state. There are others that, while socially desirable in principle, are really quite distasteful: for example, using a list of alien school children to attempt to locate illegal immigrants. Others are downright disturbing. The so-called bank secrecy act causes banks to maintain records on a whole host of transactions, and to report certain ones. Therefore, a government agency, in attempting to establish evidence of crime or just seeking clues to possible crime, may well browse through records of well-behaved and innocent people. There is a tinge of a seizure-without-search-warrant issue in that example.

It is to be noted that record-keeping systems that tend to tighten social processes must be absolutely accurate and must identify records and individuals correctly each time. Otherwise innocent people will be harmed in some way: be inconvenienced at the least, possibly embarrassed, or dragged unnecessarily through court or legal processes. How much tightening do we as society wish to tolerate? How much looseness of society do we like so well that we are willing to underwrite it financially and to forego the use of computers for some purposes?

The big, big question: How do we as a country and as a society construct the framework — partly legal, partly voluntary code compliance, partly professional ethics, partly administrative procedures, partly insurance — that will permit us to exploit the wonderful world of computing technology and its ability to manipulate information for the benefit of each and all of us while assuring that no one is treated unfairly or harmed by a record system? If harmed, what is the basis for redress and recovery of damages? How do we avoid inadvertently creating an information monster that will dramatically change the culture and the societal system that we have developed over 200 years and presumably prefer? Of this big, big question, privacy is but one small corner; I've tried to suggest other pieces of it. There is a lot ahead to be done by me and my colleagues, but there is also much for you as an educational institution, and as a faculty that is training students who are just developing an appreciation and awareness of the computer and what it can do. I certainly trust that the faculty will understand and communicate to the student that there is much need for technically trained people in public policy matters; I hope that Dartmouth will produce many such people.

Willis Ware joined the Rand Corporation in 1952. He is currently a senior member of the Corporate Research Staff. He was the first chairman of the American Federation of Information Processing Societies and has held national offices in the IEEE. In 1975 he was appointed by President Ford to be the Vice Chairman of the Privacy Protection Study Commission. He also chairs or is a member of numerous governmental advisory committees, and in 1975, was a DPMA Man-of-the-Year. He received his Ph.D. degree from Princeton University in 1951.

ABSTRACT

Technological innovations such as indexing, storage, retrieval, duplication and transmission of data have changed the factual underpinnings of copyright. Protecting the rights and privileges of authors, users, and publishers during the last quarter of the 20th century will require work and cooperation.

Copyright vs. Copy Rights

ROBERT P. BIGELOW
Computer Law and Tax Report
Boston, MA

Since I am from Boston and went to Harvard, and since I've come here to a conference sponsored primarily by mathematicians I should acknowledge my debt to a Harvard mathematician of whom some of you may have heard, Tom Lehrer. You may recall one of his small ditties in which he taught me the secret of the little success that I've had. It started out, "Plagiarize, let no one else's work evade your eyes. But be sure to call it research." In preparing these remarks I would like to acknowledge some work by President Kemeny, Anne Branscomb of Kalba Bowen, David Blair of the Vancouver Bar, Morton David Goldberg of the New York Bar and a fellow named Nick Henry of Arizona State University, with perhaps a little leavening of my own.

President Kemeny, in his book, told the story of how Gauss, the mathematician, determined the sum of the numbers from 1 to 100 by multiplying 101 by 50. Then he continued, "I once had a nightmare in which the young Gauss was back in school, but the school was being taught by a CAI computer system. In the system the computer told Gauss to take 1 and add 2 to it, then it forced him to add 3 to the result, and so on. By the time he had added the numbers to 100, he had become thoroughly disgusted with mathematics and decided to become a lawyer."

I am that lawyer.

THE FORCES INVOLVED

As we look at the forces involved in the question of copyrights and ownership of intellectual works, particularly in the publishing type of approach, there are three groups: the public, the authors and the publishers. The public needs access to information for its political decisions, for

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educational purposes, for enjoyment and for business decisions.

The author needs ego satisfaction, as is shown by the success of the number of publishing companies that advertise, "Send your manuscript and we'll make a book." You pay them, and they make the book. Some authors need money to live on. And for one group, the academics, publication is an economic need.

The publisher needs an economic incentive to justify the risk of the publication. Copyright has been the traditional method and is likely to continue to be so for some time. The publisher also needs a happy production staff. While the editorial staff may, in general, be affected only mildly by the electronic revolution, the printers are up in arms — let me just cite the *Washington Post* strike. Some of the more interesting labor arbitrations of the computer age have involved jurisdictional battles between the editorial unions and the typographical unions, with the publisher in the middle.

THE COPYRIGHT ACTS

The Constitution gives Congress the power "to promote the Progress of Science and useful Arts by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." Until recently that "limited time" in the United States was 28 years, renewable for another 28. But this year Congress passed, and the President signed, a new Copyright Act. For works that are created after January 1, 1978, the term of copyright is the author's life plus 50 years. This extension came about at the urging of authors particularly, who pointed out the possibility of the destitute novelist in his old age, with no income when his copyright had run out. The author's life plus 50 years is the usual length of protection in other countries.

This new Act is generally effective January 1, 1978. The first five sections, 101 to 105, are definitions that state what can be copyrighted. Sections 106 to 118 define the scope of exclusive rights in copyright. Section 117, which is part of that exclusive rights section, reads as follows: "Notwithstanding the provisions of sections 106 through 116 and 118, this title does not afford to the owner of copyright in a work any greater or lesser rights with respect to the use of the work in conjunction with automatic systems capable of storing, processing, retrieving, or transferring information, or in conjunction with any similar device, machine, or process than those afforded to works under the law, whether Title 17 [of the Copyright Act] or the common law or statutes of a State, in effect on December 31, 1977, as held applicable and construed by a court in an action brought under this title." So, it would initially seem that data bases and programs are not covered by this new Copyright Act.

However, what works can be copyrighted, and the questions of ownership, transfer, duration of copyright (Chapters 2 and 3 of this new Act); the rules of copyright notice, deposit, and registration (Chapter 4); and the remedies for infringement (Chapter 5) all become effective January 1, 1978, for machine-readable data bases and computer programs, *if they can be copyrighted.*

Can they? Well, the new law, Section 102A, and its associated definitions from Section 101 (when you mesh about three or four sentences together and cut out some of the duplication), reads as follows: "Copyright subsists in an original work of authorship when its embodiment is fixed in any tangible medium of expression, now known or later developed, and from which the work can be perceived, reproduced, or otherwise communicated with the aid of a machine or device (whether now known or later developed) for a period of more than transitory duration." While the Act rules out copyright for ideas, processes, principles and so on (and thus it may be that one cannot copyright an algorithm) machine-readable data bases and object programs certainly would seem to fit within the definition of what is copyrightable.

The sections of the new Act that define and limit the exclusive uses (106 to 118) represent a series of compromises between the users, authors, and publishers about hard copy, sound recording and photography. Among the subjects covered by these sections are (a) the judicially developed concept (here in the United States) of fair use, (b) photocopying, (c) cable TV, (d) jukeboxes, and (e) public broadcasting's right to use copyrighted material.

None of these new rules will apply to machine-readable data bases. We must look to the law as it is developed under the Copyright Act of 1909, and by the states.

THE STUDY COMMISSIONS

We must examine the work of two federal commissions that are now studying the situation. One is the Commission on Libraries and Information Science, an office in HEW, established in 1970. The other, established at the end of 1974 by act of Congress, is the National Commission on

Robert P. Bigelow

New Technological Uses of Copyrighted Works, commonly called CONTU, which is specifically required to study and make legislative recommendations on, among other things, "the reproduction and use of copyrighted works of authorship in conjunction with automatic systems capable of storing, processing, retrieving and transferring information." The Commission held hearings on this question in September and expects to have its final recommendations ready next August.

THE END OF COMMON LAW COPYRIGHT

The portions of the new Act that are not concerned with exclusive rights, and therefore are not excised by Section 117 (the one I read), will require prompt study and decision by proprietors and users of machine-readable data bases and programs. For example, under Section 301 of the new Act, Congress has preempted the copyright field. Until now there has been a common law doctrine of copyright, enforced by the states, rather akin to trade secret protection. There will no longer be such a doctrine. Only works of authorship that are not subject to copyright, and activities that violate legal rights and are not equivalent to the exclusive rights granted under the Copyright Act, are left to state law. Morton David Goldberg, a well-known copyright lawyer, gives some examples of what *might* be left to state law to enforce: "A consistent pattern of unauthorized appropriation by a competitor, of the facts (i.e., not the literary expression) constituting 'hot' news, whether in the traditional mold of newspaper accounts or in the newer form of data updates from scientific, business and financial data bases." Another example he gives of something the state law might enforce is "electronically or cryptographically breaching the security arrangements of the proprietor of a computerized data base and accessing the proprietor's data." Or "data access by the intentional interception of data transmissions by wire, microwave or laser or even by the common, unintentional means of crossed telephone lines occasioned by errors in switching," which I understand from luncheon conversation is becoming more and more common. Finally, he suggests that state law may have an effect on the "protection for the proprietor of data displayed on the CRT against unauthorized printouts by third parties (with or without improper access)" — i.e., the guy who tries to take a picture.

GOVERNMENT COPYRIGHTS

Another area that will require prompt study is the scope of government non-copyright. Section 105 of the new Act and its related definition provide, "Copyright protection under this law is not available for any work prepared as an officer or employee of the United States Government as part of that person's official duties." This is more limited than the current law which has been interpreted by administrators to exclude copyright protection for government-sponsored research and development.

During the deliberations of the new Act, the National Technical Information Service, which is required by law to be self-supporting, requested that it be allowed to copyright government research it published, pointing out that foreign governments and companies are making bundles from NTIS materials by just reproducing them. Congress refused. Other governments have traditionally controlled the reproduction of their writings. The British and Canadians both have Crown prerogatives and rights under their copyright acts. The new American act specifically makes works first published by the United Nations and by the Organization of American States subject to American copyright protection.

And in 1968, when Congress passed the Standard Data Reference Act, it authorized the Secretary of Commerce to secure copyright in such data on behalf of the United States Government. The legislative history shows that Congress specifically recognized that much of this data would be disseminated in machine-readable form.

These developments indicate an increasing interest by government in controlling the information it develops. This has policy implications not only for the developer and user of information, but also for the political scientist and for the civil libertarian.

DEPOSIT REQUIREMENTS

Section 407 of the new Act, to look at another problem, revises the requirements for depositing works with the Copyright Office. Copyright owners will now have to deposit within three months. Failure to do so frees infringers from statutory damages for infringement between the date of publication and the date of the actual deposit. Since unpublished works of limited circulation will be protected *only* under the Federal Act, failure to deposit these frees the infringer from statutory damages until they are registered.

The deposit requirements seem well adapted to traditional forms of copyright works. But, as Anne Branscomb has asked, how do you deposit information in computerized data bases that are being updated constantly? Do you run a printout every hour? This is one problem that may be addressed by CONTU. But the new law goes into effect the day after that Commission is expected to render its final report.

THE LIBRARY OF THE FUTURE

In Chapter 8 of his book Dr. Kemeny indicated, as have others, how the library of the future might develop, and some of the pros and cons. A study at the University of British Columbia, cited by Nick Henry, showed that 3.5% of users would either steal a book or tear out pages if the photocopier were not available. So it may be that the automated libraries of the future will not only save space; they may save on duplication and may be much cheaper.

A number of writers have suggested payment by use, not only for computerized data bases, but also hardcopy xerography. And there are indications that the technology is here, through machine accounting methods (including an adaptation of the Universal Product Code) to handle such accounting. This development may be assisted by the establishment under the new Copyright Act of the Copyright Royalty Tribunal. This new agency is charged with setting rates and settling royalty disputes in the phonorecord, CATV, jukebox and public broadcast areas. The Tribunal may well be helpful in implementing payment for the use of information.

INFORMATION POLLUTION

But we have a problem — the problem of information pollution. Authors get an ego trip from their words, and for some, publishing is an academic need. GIGO applies no less to computerized information systems than it does to accounting — for insurance premiums, for example. But the difference is that with information systems the garbage is introduced *intentionally* into the system.

May I suggest two areas for examination: Under the new copyright law, the term of protection is about 100 years. While this is excellent for Tennessee Williams, C. S. Forester, or Irving Berlin, I submit it is unnecessarily long for most nonfiction and much too long for the kinds of information that will end up in machine-readable data bases. Under current law only some 10% of the 28-year copyrights are renewed. Currently, less than half of these are books and periodicals. Most of the renewals are for musical compositions, movies and the like. Reducing the term of copyright for machine data bases to 10 years would encourage less storage of information, increase circulation of knowledge, and, hopefully, eliminate obsolete garbage.

Earlier I mentioned that delay in copyright registration under the new Act will cause the loss of statutory damages. Both the present and the new Acts provide for actual or statutory damages in the alternative. In other words, you can get what the law says you can get as X dollars, or you can actually prove that your damages are more. But the new Act increases the statutory limits to $10,000, or to $50,000 if it's a willful infringement. And the copyright holder's burden of proof is easier when he wants statutory damages. Copyright proprietors have the right to choose the statutory instead of actual damages at any time until up to the final judgment rendered by the court. Perhaps a modification of this concept, under which the information proprietor could choose statutory relief in exchange for a shorter copyright duration could be a persuasive, self-actuating vehicle for shorter copyright protection.

My second suggestion is directed particularly to the academic community. Dr. Nicholas Henry has pointed out "The 'publish or perish' diktat in universities has fostered a publication competition among researchers that has added immeasurably to the data explosion. While technology offers a means of controlling this explosion, information technology and academic realities concerning publication should combine to accelerate the life style of the professoriate. Technology greatly facilitates research, making it possible for professors to publish more, and faster. This, in turn, intensifies the publication competition on the campus, ultimately increasing the publication information."

This statement seems to be supported by the record. *Publishers Weekly* reported that 30,004 new books were published in 1975. This excludes government publications, institutional publications, and publications of theses, which, when combined, total at least an equal number. *Publishers Weekly* says this figure is also incomplete in the school and textbook area. Only 2407 of these titles (8% of the reported figures, perhaps 3% of the total titles) were fiction. All the rest (97%) were nonfiction. There were more science titles than fiction. There were twice as many books on sociology and economics as there were fiction. (Of course, there are some who consider sociology and economics fiction.) The trend of very little fiction continues in 1976.

My experience in college, and the experience of others, suggests that too often the person who can write cannot teach. And the person who can really teach, cannot write. The perpetuation of "publish or perish" combines the worst of both. It is a major factor, I submit, in the production of garbage from the academic press and from government-sponsored research by the professorial ranks.

Dr. Kemeny, in commenting on his proposal for payment based on use, summarized this idea most succinctly when he wrote, "Perhaps the greatest benefit to society would come about if some authors found out that nobody is paying any attention to what they are writing, and therefore there would be a significant decrease in the amount of worthless material that is published."

To that I say, "AMEN!"

Mr. Bigelow is a practicing attorney in Boston. He is Vice President of the Computer Law Association, a former member of the Council of the American Bar Association's Section on Science and Technology, and was the first chairman of the Boston Bar Association's Committee on Law, Science, and Technology. He is a member of the Association for Computer Machinery, where he served as first chairman of the Special Interest Group on Computers and Society and has served as an ACM National Lecturer. He has written widely on computers and the law.

ABSTRACT

Computer abuse appears to be growing rapidly, based on a study of over 400 cases. The nature of the problem and its growth rate considered in the context of new and growing uses of computer technology will be discussed. This forms the basis for some conjecture about the future of these problems.

The Future of Computer Abuse

DONN B. PARKER
Stanford Research Institute
Menlo Park, CA

I think I could find pieces in almost every talk that's been given so far that have some involvement with or some impact on what I have to say this afternoon. I'm not going to play one-upmanship with David Ahl and tell you computer crime war stories — I think I might lose that battle. This afternoon I will pose a question that I've been thinking about and talk about some of the results of studies that bear on that question. I'll talk about the rate of growth of computer abuse and say something about the enemy — the bad guys and what they're doing. Then I'll turn the coin over and look at some of the strategies for computer security that are outgrowths of looking at the problem from the point of view of experience, as I've been doing.

I've collected all kinds of incidents from which we can learn things that can help us make computers safer to use. I don't worry about whether an incident is really a crime or not, but whether there is something that can be learned from it. So "computer abuse" covers all kinds of problems, from actual crimes (where someone has been convicted of a crime), to the other extreme, where somebody has done something bad and has been fired or reprimanded. It includes business disputes and any kind of intentionally-caused losses associated with computers. I don't like to argue over whether the Equity Funding Insurance fraud was a computer crime or computer abuse or not — I just put it in my file and study it and learn some valuable things by looking at it.

In the six years that I've been looking at this problem and collecting over 430 reported cases of computer abuse, a question has been at the back of my mind. I've resisted posing this question for some time, but I think it's time now for it to be asked: Will the lack of security inhibit the advancement of important computer usage? Certainly there are instances where this has occurred, especially in government. There are instances where one of the major reasons for stopping the development of a computer system has been that the security of the system was either not articulated well enough or simply wasn't there. The National Data Bank idea, FEDNET, and perhaps several others, have been stopped, and one of the major problems was lack of security.

I pose this question at this point in time primarily because the EFT Commission is now looking at security, and also because Senator Ribicoff's Government Operations Committee is now looking at computer crime. This will give the issue some important exposure to policy makers, thus I think it's time that we ask this question. Let me give you some background as to why I'm posing it, and some information that might give us some insight into the problem.

CRIMINAL ASPECTS OF COMPUTER ABUSE

First of all we'll talk about one part of computer abuse — crime. The crimes associated with computers go by the same old names: fraud, theft, larceny, embezzlement, sabotage, espionage, extortion, and so on. But once you've named the crime, I suggest everything else about it is new. The occupations of the people doing it are new, the environments in which it is going on are new, the modi operandi are new, and the forms of the assets are new. So I suggest we do in fact have a new kind of crime problem today.

For example, consider the forms of assets today. White-collar crime has always focused on where the assets are. Willie Sutton is supposed to have answered, when asked why he robbed banks, "Because that's where the money is." Today you can ask the question, "Why is white-collar crime starting to focus on computer environments?" and the answer, of course, is, "That's where the money is." We are increasingly putting our valuable assets inside computer systems. Consider money: we've gone from bartering goods and services to precious metal. That got too heavy to carry around, so we put it in a vault, wrote little pieces of paper that say it's there, and used the paper. We found out we could use the paper just as well and really didn't need all that precious metal, so we went to a paper system. Today we have plastic money, and we have what I call electronic money. Our money is increasingly being stored in the form of electronic impulses and magnetic patterns squirted through telephone lines and processed inside computers. It's no longer in the form of paper; you can't find it any place on paper. It's in computer systems and it's in electronic form. And so with this transition of negotiable assets into electronic form we're finding that the criminal element is focusing on where it is.

In another aspect of the situation today our technology is advancing very rapidly, but the supporting functions that make it safe to use are lagging behind. Our capability to put controls in our applications systems and our operating systems is lagging behind. We do not have solutions to the computer security problem, and we don't anticipate them for another five to ten years.

Auditing is lagging behind: auditors are just learning how to audit batch-operated computers, and we're racing on to on-line, real-time, integrated, distributed systems. Auditors and data processing managers are just now starting to discover one another and to figure out how to talk to one another.

Crime, on the other hand, keeps right up-to-date with everything. This morning Ruth Davis talked about automobiles and crime. The crooks first learned how to use automobiles in their activities and then the police learned how to use automobiles to chase them. Crime is there ready and waiting for every innovation that comes along, and we have a reaction situation. I claim that with the rapid advancement of computer technology we no longer have the luxury of reaction to crime. The lead times needed to get secure systems developed, plus the rapid development of the technology, leave us no time. We are going to have to anticipate bad things that can happen with computers. We have to act, instead of just reacting to a problem when it's already out of control. I'm not saying necessarily computer crime is yet out of control — you may conclude for yourself.

THE SCOPE OF KNOWN COMPUTER ABUSE

Bear in mind that I have a very small, highly biased sample — 430 cases — out of probably thousands of problems like the ones I've collected. Figure 1 shows the growth by year. It looks exponential, but I don't think I have a large enough sample to really conclude that. It trails off because there is always a lag between the actual occurrence of an incident and when I find out about it. I always know of fewer cases for the most recent years. Putting that in more perspective we get an idea of what that curve looks like in relationship to the FBI statistics on missing funds in banks (see Figure 2). My curve is the little one just peaking over the horizon. It doesn't really look significant when seen in this perspective, even though I'm collecting cases of computer abuse worldwide.

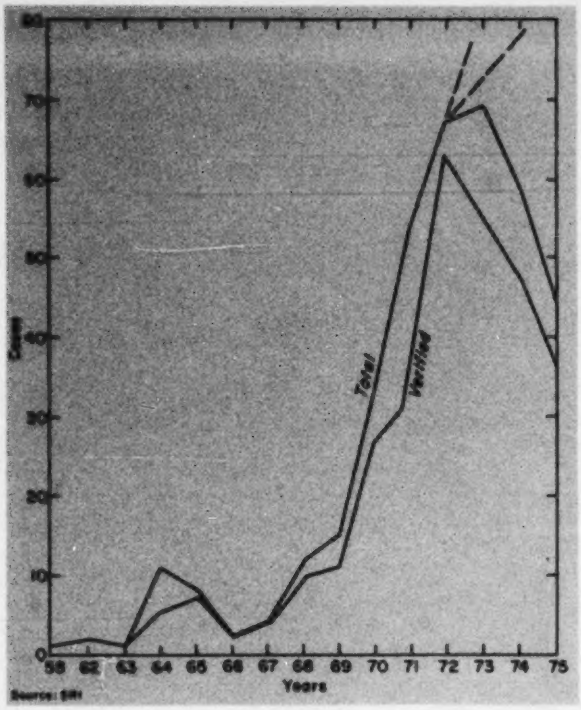

FIGURE 1

INCIDENCE OF REPORTED COMPUTER ABUSE CASES
(TO OCTOBER 1975)

Looking at it from the point of view of loss (see Figure 3), I'm finding on the order of ten to 15 million dollars a year that I can actually prove were lost. (By the way, the two-billion-dollar Equity Funding fraud is not here — it distorts my curve.) Within the last two months I've found two more major alleged computer crimes: a $14,000,000 gasoline inventory fraud in San Juan, Puerto Rico, and a $40,000,000 fraud in Chicago involving inventory. Those are the kinds of peaks on the curve. That's fairly consistent with the U.S. Chamber of Commerce estimate, that 100 million dollars a year are lost from computer fraud.

So we're trying to figure out what this problem is all about by looking at a tiny piece of the iceberg and wondering how big it is underneath. That's very difficult, and please bear that in mind when I start telling you about some of the conclusions that we're trying to derive from the studies.

THE VICTIMS AND THE PERPETRATORS

Let's take a look at the victims and find out who they are (see Figure 4). Obviously banking comes first — that's where we find the liquid assets. Banks are heavy users of computing, and banks are required by law, at least in this country, to report fraud and embezzlement.

Education comes next. I can find as many cases as I have time to look for by going to various university campuses collecting them. They tend to be students compromising campus computer systems, and they tend not to be serious relative to the amount of loss. But they are the most sophisticated, because the name of the game is how-tricky-can-I-be, not how-much-can-I-get. It is a serious problem, however, in that our universities today are almost encouraging the idea of students

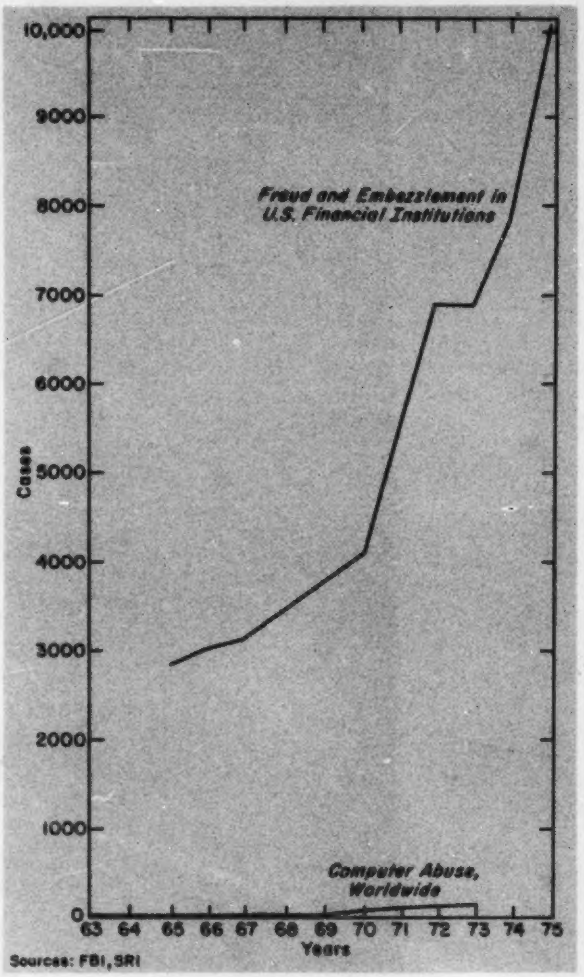

FIGURE 2

COMPARATIVE INCIDENCE OF WORLDWIDE COMPUTER ABUSE
VS. U.S. FINANCIAL INSTITUTION FRAUD AND EMBEZZLEMENT

playing unauthorized games with computers. Our students are coming out of universities into the real world with the idea that computers are to play games with, unauthorized or otherwise, and are getting themselves into trouble. A couple of students at Wayne State University were sent to prison for doing that kind of thing. In fact, I have my best case of "Trojan Horse" computer abuse right here at Kiewit. I am concerned about the attitudes that students are developing toward the use of computers. I think there's a great need for emphasis on professional responsibilities and ethical values among students, especially students in computer science since they're going to be the most trusted people in society over a long period of time.

The largest number of people who are doing these kinds of things are at the bottom of the pyramid in Figure 5. They are the people who handle the data in human readable form. This is where the highest incidence and the lowest loss per case seem to be. The fewest cases I have are among the systems designers, the implementors, the more technologically oriented people. There I find the greatest losses per case, but very low incidence. The left-hand side of the figure indicates the kinds of methods that are used: "in spec" or "nonspec." With in spec methods someone has used the computer exactly as it was supposed to be used; the fraud, whatever it was, involved manipulation of the

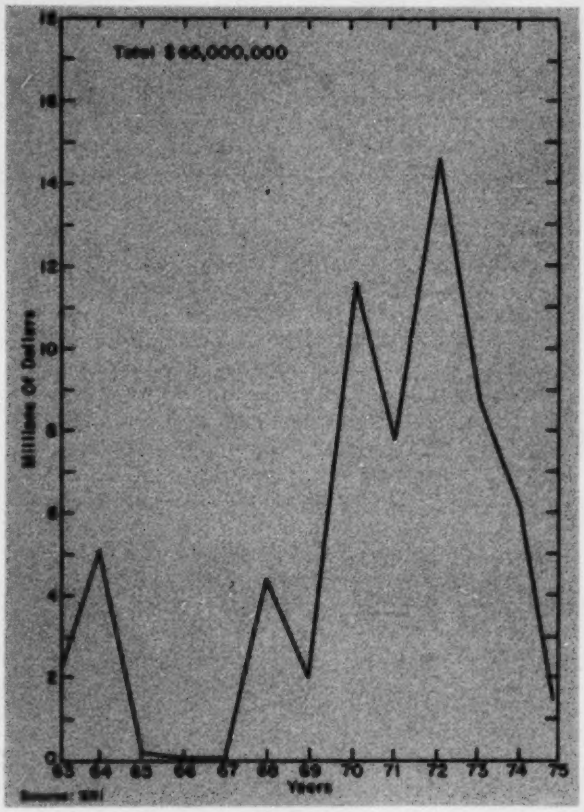

FIGURE 3

Losses in 144 Reported Cases of Computer Abuse
(To September 1975)

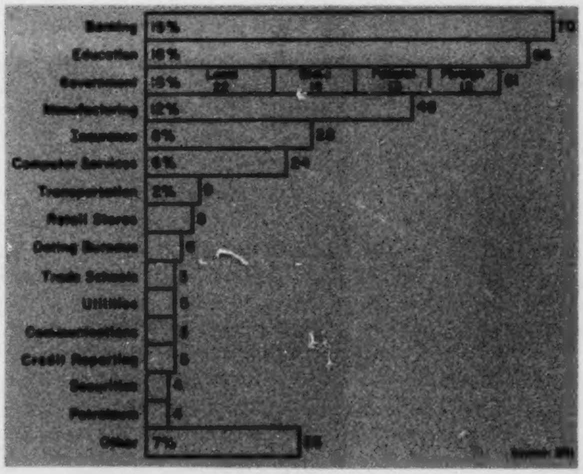

FIGURE 4

Distribution by Industry of Reported Computer Abuse, Octoper 1975
(Incidence and Percentage of 375 Cases)

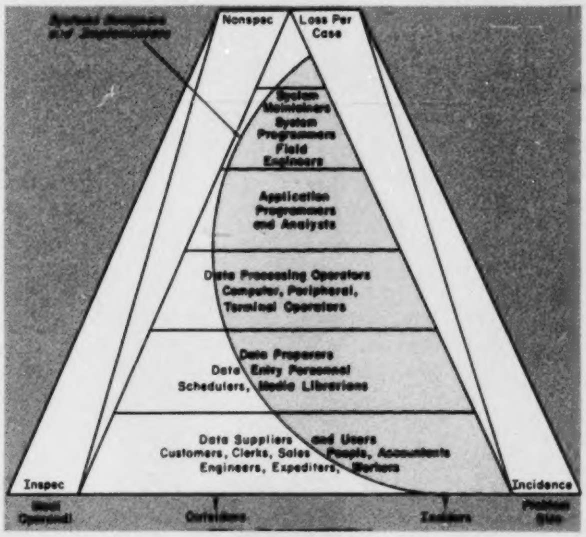
Systems Designers and Implementors
Nonspec
Loss Per Case
System Maintainers
System Programmers
Field Engineers
Application Programmers and Analysts
Data Processing Operators
Computer, Peripheral, Terminal Operators
Data Preparers
Data Entry Personnel
Schedulers, Media Librarians
Data Suppliers and Users
Customers, Clerks, Sales People, Accountants
Engineers, Expediters, Workers
Inspec
Incidence
Outsiders
Insiders
Problem Size

FIGURE 5

Population of Potential Perpetrators

TABLE 1

FUNCTIONAL VULNERABILITIES IN 362 CASES

	Cases
Poor controls over manual I/O handling	147
Weak or absent physical access control	46
Weaknesses in computer and terminal operation	43
Failure of business ethics	41
Poor control of computer programs	33
Lack of operating system access controls and integrity	24
Failure to prevent and detect time-sharing user impersonation	19
Weak magnetic tape library controls	9

data before it went into the system or after it came out of the system. Nonspec methods, which are used by the more sophisticated people, involve doing unauthorized things, like changing computer programs, or unauthorized use of utility programs.

In one of our more recent studies we identified the major vulnerability in all 430 cases. In 362 cases we felt we could determine what that was as indicated in Table 1. It's obvious, at least from the reported cases in the sample that I have, that the most common kinds of problems involve the manual handling of input/output. Secondly, they involve people being where they're not supposed to be: computer programmers having access to computer rooms and live data in their debugging stages; computer operators having access to data entry and data preparation areas, and so on. The problems that involve a failure of business ethics have to do with various cases where a company or organization made a business decision to engage in some kind of at least unethical, and likely illegal, act: for example the dating service that went into business to match people for dates, advertising they would do this by computer, and maybe they had a card sorter in the back room. Also there are more serious ones like the Equity Funding fraud which are business ethics problems. Notice that computer operating systems as the major vulnerability are far down on my list. Those include doing sophisticated round-downs and using Trojan horses, logic bombs and trap doors in operating systems, and so forth. We have very few cases like that. Maybe it's because they're so successful that we haven't found out about them. But I suspect these kinds of acts are rare because it is so easy to do things in other ways. It is easier to get someone to change some data than it is to try to change a computer program to do the same thing.

COMPUTER SECURITY

Let's turn the coin over and talk about computer security. Computer security today is a very fuzzy subject. We don't have any standards in computer security. We don't even have any accepted good practices. Everybody says you should put a tape library into a vault with a big steel door on it. Well, there is a lot of thought now that this is wrong. You should surround the tape library with glass, because the main thing you are concerned about is who's in there and what they are doing, and you can't see anybody in there if you have cement around it. That's where we are in computer security today.

What are we going to do, based on what we're learning from this experience? First of all, I suggest that almost all of the literature, all the books, reports, manuals and so on that you can find on computer security, are not addressing the problem I present. They are addressing accident problems: errors and omissions and natural disasters. The methods proposed for computer security today are simply not adaptable to protection from intentional acts. Table 2 shows the differences in the issues and characteristics that derive from these two kinds of problems, from errors and accidents, and from intentional acts, to show that the threats are significantly different. Therefore, we need different kinds of strategies.

Most books on computer security have checklists. The idea is that you can use the "cookbook" approach: if you do all the things it says to do in checklists, then everything is okay. Well, I suggest everything is not okay, because the bad guy doesn't use the same checklist you do. This is what leads to what I call the "Maginot Line"

TABLE 2

SECURITY DIFFERENCES

Errors	*Intentional Acts*
• Few unsolved problems	• Many unsolved problems
• Single, isolated act	• Complex
• One person	• Frequent collusion
• Simple motive	• Complex motive
• Obvious sources	• Obscure sources
• Minimum skills at issue	• Maximum skills at issue
• Loss limits	• Large, undetected losses
• No premeditation	• Fear of unanticipated detection
• High incidence	• Low incidence
• Adequately documented	• Little adequate documentation
• Checklist applicable	• Game strategy
• Incremental safeguarding	• Weakest link
• Safeguards are safe	• Safeguards attacked

syndrome. A big monolith of security is developed: man traps and logging, accessing controls and badges, electronic fences built into computer systems and all that kind of thing. The bad guy is going to "end run" this Maginot Line every time, because he's not looking for where the system has strengths — he's looking for the weaknesses. When you add a safeguard for an *error* or *omission* you have increased your protection by some incremental amount. But when you add a safeguard to protect against *intentional acts*, you have not necessarily increased your protection by some incremental amount. In fact, you may have reduced it, because you have plugged an obvious hole, which tells the bad guy that he should go look somewhere else. Then he finds a much safer hole to reach into to grab the cookies. I suggest that an entirely different kind of strategy is needed.

In isolated acts of errors and omissions, we're concerned essentially with people's minimum level of competency. In intentional acts we're dealing with the maximum skills that people have — their most advanced capabilities, not their least advanced. The loss incidents from errors and omissions are pretty adequately documented. We have been beating away at errors and omissions for 25 years now. We generally know what to do. It's a matter of weighing the cost against what we get for that cost. We put up with a certain amount of errors and omissions, and we can live with that.

When it comes to intentional acts, however, we have a different kind of situation. They occupy a wide spectrum. There are the high-incidence, low-loss acts that go on all the time, and these we keep under control, for instance, credit card fraud. It goes on all the time. Our society has learned to live with credit card fraud. Sometimes incidence goes up a little when some kind of new service is offered, and then the credit card company or bank beats it back down by adding more care and more security; so it stays within a level of activity that can be tolerated.

At the other end of the spectrum of intentional acts we have a very different problem. It has a low occurrence probability, it happens very infrequently, but when it does it's a real whopper. The losses are extremely large. In fact just one crime could put a large organization totally out of business. But the probability of its occurring might be extremely small. Here the problem is how to justify investing money to protect an organization against something that's only going to happen once in a hundred years, but when it does happen it's going to ruin the company. That's very difficult to sell to management. It's easier to convince management to do something about problems at the other end of the spectrum, because you have lots of statistics and can show that it is happening.

The last item in Table 2 involves safeguards. With accidental problems you can generally assume that the safeguards, once you have installed them, are going to work. With the intentional-act kind of problem, however, the safeguards are attacked along with the assets. You have to assume that the safeguards are going to be attacked as well as the assets that are being protected in a computer system.

STRATEGIES FOR COMBATING COMPUTER ABUSE

Thus these are two very different problems: security from errors and omissions and security from intentional acts. This leads us to the question, what kind of strategy are we going to use if we can't use the ones that seem to be accepted today? Valuable techniques in doing risk analysis are being developed today. Some important techniques have come from IBM, and the National Bureau of Standards, Task Group 15 under Ruth Davis, is developing some techniques in risk analysis. I call this "security by the numbers." This is trying to assign probabilities and expected loss values to assets to determine what expected loss might be, in order to help judge how much to spend and where to spend it for protecting an organization. I think that kind of objective approach to security is an important part of the new strategy.

But along with it we need a subjective approach, and I think that it has to be based on the idea that you have to think like the enemy if you're going to defend yourself from him. That's why I've spent many hours sitting in prison cells talking to computer programmers. That's also why I might sound a little paranoid about the subject. But I think it's very important to know who these people are, and to develop a strategy based on what I call "scenario threat analysis," where you develop a set of stories and use the set of stories for several purposes. Each story depicts a certain subpopulation of people who have the skills, knowledge and access to cause a loss, and tells how they might do it in a computer environment. You can play these stories against an organization and find where there are controls and safeguards, and where there aren't any.

We've had some experience with clients in applying this scenario technique now. In one case, a large commercial time-sharing organization, we developed 28 scenarios that described all the major threats we could think of in this particular environment. We played these theoretically (not the tiger team approach, but theoretically) against the organization, looking for weaknesses and strengths. We found various areas where there was too much strength; there were too many safeguards and controls and they didn't need that much protection. In other areas there weren't any. Thus we frequently recommend a change in where the resources are put, and not necessarily an increase in the resources. In fact, in playing scenarios against one government computer service run by GSA we concluded that they didn't really need any security at all! The system was not being used for anything particularly sensitive, and the main concern was errors and omissions. We said, "Forget about trying to protect the system from intentional acts. Nobody wants to attack the system." They were working away at checklists, trying to develop ideas for security, and worrying about people who were going to try to break into their system. There is no value gained by breaking into it!

In thinking about the security of assets, keep my GSA example in mind. We talk about security in rather absolute terms: "Yes, we have security," or "No, we don't have security." But security has to be measured relative to the value and importance of the assets that are represented in a computer system. We can do that by developing a risk-analysis approach and, in parallel with it, the more subjective scenario approach, playing the bad guy.

Scenarios are also useful in conversing with nontechnical people, especially with management. You've got something that you can grasp in a story. You can tell a nontechnical top manager how someone could cause a major loss to his organization, and he can readily understand it in that form. If you give him a matrix and a sheet of numbers and say, "Here's where the vulnerabilities are," it doesn't have nearly the impact of a set of scenarios that show how he can really be ripped off. So the scenario approach has that great value as well.

USING SAFEGUARDS

We come down to one last point in this strategy: what do you do once you've discovered that you have a lack of certain safeguards and controls? Suppose you have developed a menu of all the possible controls or safeguards that you can think of. The use of checklists is helpful here. I suggest that we then use a set of principles to evaluate any particular safeguard that we're considering. I haven't time to go through each one of these presented in Table 3, but some of them are less obvious than others. Cost is most important. How much should you spend on a safeguard? A safeguard involves much more than just the initial cost, because you have to audit it on a continuing basis. You have to instrument the safeguard; so you will have warning if it is attacked and to tell if it's working. It has to be auditable. It also has to be sustained over time. It's nonsense to put in a safeguard knowing it's going to work the first day, maybe the first week, but not having any assurance that it's still working two years from now.

TABLE 3

SAFEGUARD PRINCIPLES

- **Cost effectiveness**
- **Automatic**
- **Override**
- **Overt design and operation**
- **Least privilege**
- **Entrapment**
- **Independence of control and subject**
- **Universal application**
- **Compartmentalization and defensive depth**
- **Isolation, least common mechanism**
- **Completeness and consistency**
- **Instrumentation**
- **Acceptance and tolerance by personnel**
- **Sustainability**
- **Auditability**
- **Accountability**

People have to be willing to accept safeguards; you can't just impose them. If you impose a safeguard by telling a programming group that there are certain commands in the programming language they're not allowed to use and you change the compiler to prevent their use, that's waving a red flag in front of a bull. That's a challenge! They're going to figure out how to use them no matter what you do. Instead, approach the issue by saying, "Listen, people, here's why we don't want you to use these particular commands: they're vulnerable from a security point of view, and we want to protect your job, and our employer . . . " Security has to be sold. You cannot impose it on people, because people are constrained by security, and whatever you do they've got to be willing to make it work before it's really going to work. This, too, is part of the idea of developing a different kind of strategy from the ones that are commonly proposed in the literature.

Donn B. Parker

PREDICTIONS OF FUTURE ABUSES

Let me go on to talk about what's going to happen in the future. You've heard about all the things that have been happening so far. You read about them in the newspapers. Where might this problem be headed? We're certainly going to have more massive frauds like the Equity Funding case, because you can see the same characteristics of Equity Funding in many other organizations. Consider electronic funds transfer systems as just one example. Banking and our financial world have been based on trust. But trust involves face-to-face interaction with people. Now we're limiting a lot of the face-to-face interaction of people; it's face-to-face interaction of computers. And people hide behind their computers. So it changes the game relative to the financial system and transactions based on trust.

Consider organized crime. Two weeks ago I was lecturing in Milan, Italy, and I talked some about organized crime and the Mafia. I got through the talk alright. But the next day the people sponsoring my lectures said, "You know, tomorrow you're going to be lecturing in Rome, and there are going to be some Sicilian bankers in your audience. We think it's a good idea if you not mention the Mafia." They said that the commissioner for the investigation of the Mafia in Italy was killed last month. Well, needless to say, I didn't get into this subject as much as I had intended! Four days later I was in Skoki, Illinois, talking about the same subject, and I guess I could have used the same warning there. I had read in a newspaper article that Mr. Robert Bullock, Director of the Illinois Bureau of Investigation, is currently holding a series of meetings with the banking community in Chicago, and I talked to him about it. The banking community is telling him that organized crime is now moving into banking in Chicago by coercing EDP technologists: they get programmers, computer operators and data entry people into debt through loan sharking and gambling, and then get them to do unauthorized and/or illegal things for organized crime. For six years I've been going around saying, "Organized crime is coming; it's ready and waiting as soon as the stakes are high enough. We can certainly anticipate it." And now it looks as though we're getting some significant evidence that organized crime is starting to move in. With EFT coming along the way it is, one couldn't imagine a more attractive kind of transition of financial activities in our society, to interest organized crime. It's ideal for that.

Organized crime should have three interests in computers: (1) the desire to perpetrate crimes against systems and through computer systems; (2) organized crime is big business and any large business needs a computer, so we can certainly anticipate that organized crime will be, if they're not already, using computers in their major business activities; (3) the Justice Department is using computers to combat organized crime and you can certainly imagine that organized crime has great interest in anything they might be able to do to discourage this use of computers, or in any case to confuse the data about them that are being stored in those computers. So there are three ways in which I think organized crime is going to be moving in. I have only four cases involving organized crime, and they're isolated, incidental ones, but I think it's something we'll see more of in the future.

Other kinds of abuse we might see more of in the future involve injury of people: computers are being used increasingly in process control; Ruth Davis mentioned air traffic control and intensive care of heart patients by monitoring them with computers. This brings up the issue of malpractice suits and murder by computer — I've only seen that on Barnaby Jones on TV so far, but it's not out of the realm of pssibility.

We are finding that wiretapping is *not* a problem today, and you might ask, at least from our experience, "What in the world do we need cryptographic protection for?" I've only been able to find one case of data transmission wiretapping, and that was an oil leasing situation up in Alaska. One explanation is that it's so easy to do without detection. It goes on all the time, and nobody's finding out about it. If you look at all my cases you'll find that they have almost all been discovered accidentally. So you can certainly wonder what the really smart guys are doing! However, I conclude that wiretapping is really not a problem today, because the two ends of the transmission line are still so vulnerable. Why go to all the trouble of tapping a wire and trying to figure out all that garbage coming over it, when for less money and less effort you can get someone in the data processing department to tell or give you what you want to know or do something for you? People in data processing still assume they function in benign environments; they will do anything for you. It's much easier to do something bad involving the computer by many other ways than by going to all the trouble of tapping a line.

However, as far as the future is concerned, as we tighten up both ends of the line, then the line itself becomes the weakest link. In intentional acts a crime is based on the weakest link; you go where the system is the weakest to attack. Some day in the future, data transmission may become the weakest link. In that case we'll have cryptographic protection coming along just in time so that wiretapping may never be a problem. It seems we concentrate on cryptographic safeguards today because it's a great solution, not because there is an urgent problem.

We will have time-accelerated frauds. People say EFT eliminates the float time for checks to clear through banks; therefore, you've eliminated a range of banking crimes called "kiting" that uses the float. But the people don't really seem to understand that the float is not eliminated in EFT. It is merely reduced from days down to milliseconds. There's still a float there, but we're also considering automated crimes that operate in milliseconds. Therefore, the kite concept can still be used. We're creating some scenarios on that right now, figuring out how one can do the equivalent of a check kite in an EFT system.

We will have geographically independent frauds. A burglar in the past had to break into a bank in order to attack the vault. Today computers are now the vaults; that's where our assets are stored. When you put a computer on-line to a dial telephone system you have done the equivalent of moving the vault door into the burglar's own bedroom and saying, "Here's the vault door. You now have all the time you want — you can take years, if you want to, beating away at this vault door with your computer terminal in the privacy of your bedroom. Have at it!" That's what we have told the criminals in developing our computer systems that are on-line to telephone systems. I have spent a lot of time with "Captain Crunch"; he's John Draper, the hero of the "phone phreaks." He said, "Trying to attack computers with all these trap door techniques and so on, that's too hard. Any computer that's hooked up to a dial-up telephone system, you know that's simple!" We have telephone freaks all over the world who are getting into telephone systems, getting into test loops, who are capable of bridging onto data transmission lines, picking up the passwords and then using the passwords to do whatever they want in a system as imposters. Captain Crunch is in jail right now. That's the worst place they could have put him, because he has a wealth of technical knowledge and he's not going to resist physical coercion in jail. He's going to spend four months giving seminars, and you can anticipate we're going to have a lot brighter, more technically competent criminals coming out as a result of good old Captain Crunch.

Let me conclude my conjectures about what's going to happen in the future by talking about *white-collar crime — in general —* not just computer-related or technological crime, but business crime of all kinds. I suggest that the incidence of business crime could go down over the next few years; we could have fewer cases of business crime. Here are my reasons for it. The introduction of computers, even without security, has resulted in a significant increase in security from the point of view of incidence: there are fewer people who have the skills, the knowledge, and the access to do bad things in a computer environment, compared to all the people who knew how to do these things in equivalent manual systems. And of course, in addition to that, we are getting better at computer security. Each time we add protection to a system we reduce the number of people who have the skills and the knowledge to compromise it, or who are willing to go to the effort.

In addition to the incidence going down I suggest, however, that the losses per case are going to go up very dramatically. I already have some evidence from my file of cases that this is true. The average loss among all my cases is $450,000 (not including the Equity Funding loss of two billion dollars). But the average missing funds case in banking in 1975, as reported by the FBI, was $19,000. We generally find that when a crime is automated, the losses are larger. And you might anticipate that. If you figure out how to find a window into a computer system of some kind and you have an automated process going on, it doesn't matter whether you steal $2,000 or $2,000,000. It's just another couple of zeros, and it makes little difference in the technical methods we find people using. And, of course, you also know that your probability of going to jail is much lower if you steal $2,000,000 than if you steal $2,000. So why not go for broke? It's all there; just run your crime for another couple of milliseconds, and you're on your way. A programmer once told me, "I don't understand why people think I did something so wrong. I only changed two numbers in that system for three ten-thousandths of a second. Now surely doing something for so short a time could not be very wrong and would have been even less wrong if it was only one millisecond." People can rationalize doing bad things in new environments so easily, because it's never been done before. It makes it very easy for people to get into difficulty.

In summary I suggest that these things may happen: the incidence of business crime may go down, and the loss per case may go up dramatically. When I say this, Bob Bigelow, among other people, always has some challenge like, "What about the massive increase in minicomputers in informal environments? The people are still going to be there, and it's going to involve computers, and the incidence going down is not very believable." Well, computer security is effective with minicomputers as well, but not to the same degree as with large computers. And with minicomputer installations, again, you still find fewer people who know how to do bad things. In an automobile dealership they now have a small minicomputer. Previously lots of people knew where the files were, knew how to get into and read the files. Now just two people know: the programmer and the general manager of the dealership. All you have to do is trust those two people, and everything is fine.

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ABSTRACT

The publication of *World Dynamics* and *Limits to Growth* by a team of computer modelers at MIT has precipitated a flood of global modeling studies around the world. The conflicting results and differing approaches may tell us more about the political context of current modeling efforts than they do about mankind's future. In his remarks Dennis Meadows, director of the MIT effort, will summarize current activities to forecast man's long-term future with computer models and will describe the research goals of IIASA, the International Institute for Applied Systems Analysis.

Global Simulation Models — Take Your Pick

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The opening text for my remarks is from Lewis Carroll's *Through the Looking Glass*, Chapter 5, entitled "Wool and Water." It is a dialogue between the Queen and Alice.

> "That's the effect of living backwards," the Queen said kindly: "it always makes one a little giddy at first —"
>
> "Living backwards!" Alice repeated in great astonishment. "I never heard of such a thing!"
>
> "— but there's one great advantage in it, that one's memory works both ways."
>
> "I'm sure *mine* only works one way," Alice remarked. "I can't remember things before they happen."
>
> "It's a poor sort of memory that only works backwards," the Queen remarked.
>
> "What sort of things do *you* remember best?" Alice ventured to ask.
>
> "Oh, things that happened the week after next," the Queen replied in a careless tone. "For instance, now," she went on, ". . . there's the King's Messenger. He's in prison now, being punished: and trial doesn't even begin till next Wednesday: and of course the crime comes last of all."

We might, in thinking about that, have some sympathy for the King's Messenger and suspect that it's a rather poor sort of society that puts the punishment before the crime. But if you stop to think about it, the plight of the King's Messenger is not very much different from that of many companies and individuals in our country today. A very large electrical utility in New Hampshire, for example, now faces the loss of $300,000,000 in investment, not because of anything they've done, but rather because it's expected that their installation might do something in the future. The people who have accustomed themselves to high incomes from the manufacture of aerosol cans are being similarly punished now for a crime which is not imagined to occur until some point in the future: that is to say, of course, the dispersal of our ozone layer. And many other corporate and personal organizations are increasingly hedged in by requirements placed on them now, in anticipation of consequences which might first arise at some point in the distant future.

This, in the abstract, seems unjust; in the concrete, however, it is an extremely appropriate kind of activity, when we begin to recognize that in more and more ways the things we do now have consequences that propagate far into the future. In the old days when change did not occur very rapidly and when the impact of man on his environment was minimal and could be reversed with minor cost, there was not much incentive to look ahead as a basis for current actions. Experience was an appropriate basis for wisdom, and we could abide by the words of Aristotle, "Those who ignore history are destined to repeat it." But now change occurs rapidly, man's impact on his environment is often irreversible once it is initiated, and we no longer can look simply to history for guidelines about what should be done today.

Instead, there has grown up a new industry, a sort of backwards memory, the process of developing models that forecast the future as a basis for deciding what we ought to do today. This industry has only grown up to significant size since the advent of modern computers, and indeed it has only been in the last five to ten years that this activity has assumed any kind of consequence. Today, the provision of these backwards memories in the form of computer models certainly takes well over $100,000,000 a year, and perhaps several hundred million dollars a year, of corporate and governmental investment. The National Environmental Policy Act mandated environmental impact assessments, many of which are done with computer models. ERDA currently invests tens of millions of dollars a year in forecasting which of several different kinds of energy policies might achieve specific national energy goals in the 1980's and 1990's. The World Bank is engaged in analysis of the future using computer models to weigh alternatives in allocating its economic development funds. Corporations from the consumer goods to the heavy equipment industries are engaged in market research forecasting models. The General Accounting Office and the Office of Technology Assessment both provide these kinds of inputs to Congress. Even at the state and local level, planning agencies are beginning to use backwards memories — computer models that forecast out into the future — as a way of anticipating future crimes or determining rewards that might be used in order to decide what ought to be done today.

I have, with my associates, been involved in one rather small aspect of this developing field over the last six years, that component which deals with global models. I'd like to describe that field today, not because it permits any very profound conclusions yet, but because it is a small microcosm of a burgeoning industry.

It is only over the last six years that global modeling has become a major endeavor. During that period, social and natural scientists, no more than 75 or so in number, in the United States and probably six or eight foreign countries have begun experimenting with computer-aided prognostications of the distant future. Over that time, their work has certainly not accounted for more than a microscopic fraction of the total investment in computer research activities or human interactions; the reports they've generated wouldn't stack up very high against the documents produced even by a medium-sized company's accounting department over that period of time. But these global modeling efforts have attracted a good deal of public attention, even in some cases had a modest amount of political impact, and I think their contribution is, at least in the future, potentially very great. So this morning, I'd like to deal with the analysts who have been involved in this area and think about these first crude, prototype models that they have developed.

DEFINITIONS

First, I'll start off with a few definitions, then give a sort of newspaper account of the current status of eight global modeling efforts. I'll illustrate the differences which lie within each of these efforts by citing the conclusions they put forth in one area, food, and then finally suggest a set of questions that you might use in deciding which of these conflicting images of the future you most prefer. The thing to keep in mind is that we all need some model of the future because we or our representatives are day by day engaged in decisions that have very profound and long-term impacts. If we continue to make those decisions or to reward those who act on our behalf on the basis of short-term considerations, then the long-term model we have is essentially that the distant future will be very much like the present. That's probably the one long-term model we know to be wrong. I suggest that we can do better than that if we begin to think about some of the criteria we should apply.

First, the definitions. What is a global model? What are the distinguishing characteristics of these eight efforts which differentiate them from the very much larger amount of computer-aided analysis that goes on all the time? A global model is a set of mathematical equations with the following characteristics: it is usually a set so large that it virtually mandates the use of computers for analysis; the equations typically deal with the behavior and the interaction of social, physical, and biological factors; they relate to issues which take place over very long time periods, several decades or more; and the issues are of widespread interest across many different institutions and in many different regions of the world.

Of course, economists and social scientists have worked since the early 1950's to develop mathematical models that explain specific social, demographic, or economic factors. Their work has grown increasingly sophisticated and useful and in total it certainly would be several orders of magnitude greater than the work going into global modeling. But I wouldn't term those models global models. They are typically short-term; most economic models deal with a period of only a few years or so. They typically focus on only one kind of factor — economic, demographic, biological, and so forth — missing out on many of the important interactions which come into play over longer time periods. Fortunately, there's not much disagreement over this dichotomy. Most professional economists have gone to great lengths to dissociate the kind of work they do from anything which falls under my purview today.

The second definition would be the term *forecast, prediction* or *prognostication*, terms which I use interchangeably. I use these merely to describe any useful statement about the future — useful in the sense that it decreases uncertainty about some aspect of reality that is of concern to current decision makers. Now one can decrease uncertainty without making a precise prediction as that is normally understood: that is to say, without saying that some particular variable will have a particular, precise numerical value at some instant in time. Astronomers can make such exact predictions; global modelers cannot. All they can do, at best, is identify some of the inherent tendencies in the global system, trace out some of the evolutionary paths, identify those that are favorable and unfavorable, and, if they are very skilled, begin to indicate certain policies that would tend to increase the probability of favorable outcomes and decrease the probability of unfavorable outcomes. In some sense global modeling provides a function like radar on a ship. It projects out the future course in terms of current velocity. It doesn't predict that a collision *will* occur, when that becomes indicated as a possibility on the screen, but rather suggests that collision is one of a number of outcomes. If the captain pays any attention to the radar operator, radar can help to set in motion some factors which will eliminate the particular collision outcome as a possibility.

The third definition is that of *planning*, because there has been a good deal of confusion about the difference between *global modeling* or *forecasting* and *global planning*. Forecasting requires a certain expertise in the art of modeling and great insights into the causal factors that influence the behavior of physical, biological, and social trends over time. I would say good progress is being made in that area. Planning requires forecasting in the sense that I have described it, but it requires more than that. It needs a statement of goals and some strategy for allocating scarce resources among competing needs so as to attain those goals. It requires drastic changes in the political system so that individuals and institutions become less short-sighted, less egocentric, and more willing to objectively analyze the policies which are under their discretion. I don't see very much progress in that area; indeed, I would even argue that global planning, in the sense that is normally understood, would be a very negative direction to take.

EIGHT GLOBAL MODELS

With that vocabulary in mind, let me actually describe what has gone on or is going on today around the world in the area of global modeling. I will mention briefly the eight significant efforts in the field. It is an appropriate time to do that; we've just come through the first wave of global modeling efforts. Most of the things I'll describe here are essentially complete, and I don't know of any new efforts that are getting underway. I think we're in a period of consolidation and refinement, and it's appropriate now to look back and see what has been accomplished. Criticisms of global modeling would include a stack of literature five or ten feet high, but the basic references — those which put forward a specific model and try to trace its implications — are relatively few in number. To the extent I am aware of them I have put all of them in the bibliography (see "References").

The first global model was put forward by Jay Forrester at MIT in 1970. He organized a meeting of the executive committee of the Club of Rome at

MIT to provide them with two weeks of information on the application of computer modeling techniques to social issues. As a basis for that brief seminar, he put together a world model called WORLD2, which was rather straightforward. It dealt with the world as a single entity. It did not regionally disaggregate the variables. It had five sectors in it: agriculture, pollution, population, economic development, and natural resources, and about forty significant variables. It was written in the Dynamo language and was technically a continuous, deterministic simulation language and model. Its time horizon was from 1900 to 2100. It received no outside funding, was indeed carried out by Forrester on his own time, and it produced one book, *World Dynamics*, which provides the equations for the model and which has been instrumental in bringing that model into the classroom around the country. Forrester is not continuing to work on global modeling *per se*. At the moment his staff at MIT is entirely preoccupied with the development of a large and complex, twelve-sector, macroeconomic model of the United States economy whose focus lies in the area of economic cycles with a time horizon again of about 1800 to 2050.

On the basis of Forrester's work, the Club of Rome decided that they would like to fund further research in this area and supported Donella and myself in the effort to put together a small team of scientists and students at MIT. We worked for two years on the development of WORLD3. WORLD3 is also a continuous simulation model written in Dynamo. Its time horizon is from 1900 through the year 2100. It also treats the world as one region. It also has five sectors, those which were present in Forrester's model. We took the 40 variables and disaggregated them to about 120, in order to facilitate statistical estimation and the explicit incorporation of a wide set of demographic, agricultural, and other kinds of theories. The result of that model, as you will see in my later remarks, was not significantly different from the earlier work, but it made the field much more accessible by bringing into the model terminology the vocabularies and theories of a wide set of professional disciplines.

Our work was funded: it cost about $200,000 to do the second model, and that was secured through the Volkswagen Foundation via the Club of Rome. The work resulted in three books which are listed in the bibliography. We have provided all the equations and data underlying our analysis, and it is possible for people to implement the model elsewhere, to experiment with it and test our results.

None of the people associated with this second effort are still engaged in global modeling. They have dispersed, now being professionally active in at least four countries, and are engaged in a whole set of resource-related studies designed to force specific regional and national decision makers to deal with the quesion of growth limits within specific fields. Fish, forestry, land, and oil are four resources which are currently under study through modeling by this group. There is now quite a large body of literature in each of these areas.

In 1971 I went down to Rio de Janeiro as part of the Club of Rome effort to disseminate information about our work, and there I briefed a group of Latin American social scientists on the early results of our study. They found themselves quite dissatisfied with our conclusions and with the preoccupations of our group, and therefore set out to develop a Latin American global model. They located their effort at Bariloche, which is a research institute up in the mountainous area of Argentina. They secured funding, again via the Club of Rome, from the International Research Development Commission in Canada, a government-funded group that allocates money to research and to development issues. They also received about $200,000, and they began to develop a model reflective of their viewpoints.

Their model is written in Fortran. It is an econometric model in its basic form, and the equations which result are subjected to some optimization scheme, with a goal of understanding what would have to be done to bring basic minimum standards of health, employment, nutrition, and so forth to the world's population by the year 2000. Their time horizon is 1960 to 2060. They divided the world up into four regions. Interestingly enough, three of those regions were Latin America, Africa and Asia. All the rest of the countries in the world, which of course, constitute something like 80% of the gross world product, although not 80% of the population, were lumped into the developed region. They have five sectors, including food, labor, technology, trade, and economic output. I will summarize the conclusions of their study. They are very different from the ones which I have already discussed.

Information on the Bariloche study is somewhat more difficult to obtain. There is a general report which has been published in Spanish; they're looking for an American publisher. The IDRC has published a small pamphlet, which I've cited in the bibliography, that provides basic information about the models but does not provide the equations. I suspect that the equations are available from the research team if you can find it. I don't believe that further work is underway at Bariloche in global modeling. Indeed, I heard a rumor, which has not yet been substantiated, that the new regime there called Bariloche and indicated that the tanks were on the way, and that if they found anybody up there when they arrived, the social scientists were going to be in real trouble; I think the consequence of that is that the team has dispersed.

The fourth significant effort was that undertaken by Mesarovic and Pestel. Mesarovic, the director of the systems research center at Case Western Reserve University, and Pestel, the former president of the Technical University in Hannover, Germany, developed a model in many ways like the MIT models.

It is a simulation model, this time written in Fortran. It is regionally disaggregated. They divided the world into ten different sectors, and within each of those sectors modeled food, population, resources, and so forth. In some ways it's much more detailed than our models. Their food sector, for example, has 26 different commodities. In other ways, it's much more aggregated. While we went to great lengths to understand the determinants of fertility, for example, they treat that as simply an exogenous variable which has to be fed in by the analyst between 1960 and 2060. Their work was also funded by the Volkswagen Foundation, by the National Science Foundation, and other sources. It has resulted in two publications, the first a general report called *Mankind at the Turning Point*, which is in some ways like *The Limits to Growth*. It does not provide the equations of the model, but attempts to give some indications of the general structure and the conclusions that resulted from the work.

The Mesarovic-Pestel team briefed a group of scientists at the International Institute for Applied Systems Analysis outside Vienna for one week on their model two years ago, and from that resulted a six-volume technical report. The technical report gives more details on the model but still does not provide enough information for anyone to independently implement the work. Indeed, the model has now become proprietary, and it is being sold by consulting companies that resulted from the original Mesarovic-Pestel work. This is one group, therefore, still engaged in global modeling, and Mesarovic and Pestel have been successful in convincing Iran, Germany, Venezuela, Egypt, and now I understand the Organization for African Unity, that each of those regions should put substantial money into the elaboration of the Mesarovic-Pestel model to develop some policy guidance to these countries. The total investment in this modeling effort probably now exceeds $1,000,000 and continues apace.

Another normative effort, one designed to understand how we can bring the world's evolution to some satisfactory point within the foreseeable future, was undertaken by Hans Linnemann and his associates in Holland. They focused exclusively on food, and addressed the question, "How can we feed a doubled world population by the year 2000?" Their model is a recursive simulation model; it has some static economic assumptions built into it, such that it finds the equilibrium point which equates supply and demand year after year through time. The time horizon is 1972 through 2010. They differentiate among 106 countries, and within each of those countries there are about 12 consuming sectors, so that they have 1272 consumption sectors in the model. It takes 20 minutes of CPU time to run through one analysis of the model, which makes sensitivity testing on each of the 1272 equations somewhat difficult. This was funded by the Dutch government — principally by the allocation of funds which were to employ out-of-work scientists, which somewhat restricted Linnemann's team, but since there were a lot of out-of-work scientists in Holland at that time he did get a pretty good group together — and by the Dutch industry, which in a number of cases volunteered one of their scientists to be on loan at no cost to the effort. There is an interim report available, and final reports are about to be published. Again, no equations are available in the published literature at the moment, but they will certainly be available from Linnemann. I think in this case no further work is envisioned. Linnemann views himself essentially as an economics professor and plans to go back to teaching. The team will disband, the corporate scientists going back to their companies, and the formerly unemployed scientists either going back to the welfare ranks or, hopefully, picking up something in an expanding Dutch economy.

The sixth effort, which has just recently been released, was that undertaken by Leontiev in this country under contract for the United Nations. It was actually paid for by money provided by the Dutch government. This is an input-output model in its conceptual structure, and it is what one might call pseudo-dynamic in the sense that it projects a set of scenarios for 1980, 1990, and the year 2000. Leontiev divided the world into 15 regions with 45 sectors each, 4 for food, 9 for resources, 22 for manufacturing goods, and so forth. The first report has just been issued by the United Nations, and two volumes of technical data are promised. Leontiev has recently moved down to New York from Harvard. I don't know what plans are in place for the continuation of that effort, though I suspect that his model will be picked up and extended.

Finally, there are two other global modeling efforts which are somewhat different from the first. One of those, that undertaken by Sussex University, was in fact an effort in counter-modeling, defined as taking an existing model and adapting it in order to prove that it's invalid or that it leads to conclusions different from the ones originally suggested. The Science Policy Research Unit at Sussex received British government funding to do counter-modeling with our model, WORLD3, and they published a book called *Models of Doom*. They did not create a new model except insofar as the addition of different numbers or slight structural changes to our model would constitute a new model. Suffice it to say that the Sussex group felt that, working with our model, they were able to introduce changes which they felt to be plausible and which they thought led to conclusions very different from the ones we have put forward. At the back of *Models of Doom* is our assessment of their effort, so I won't comment on that any further. The Sussex group is, in itself, engaged in modeling full-time, but most of their work is short-term and narrow in focus and thus would not qualify as a global modeling effort. However, they continue to be active in reviewing global models; indeed, the United Nations has just hired them to do an updated review of the global models currently available.

The last effort to which I'll refer is that by Herman Kahn. This is not really a modeling effort in the sense I've defined it, because no set of mathematical equations manipulated by a computer is involved. Still, the conclusions put forward are in the same arena as those conclusions put forward by the other efforts, and the difference between Kahn's point of view and that manifested by several others indicates what we might call the state of disarray or the contradictions which exist within the field. His results are put forward in a book called *The Next Two Hundred Years* which is, I think, envisioned as the first of a long and continuing series of reports on mankind's future over the next two centuries. The Kahn effort has been principally funded by United States industry. There is a large group of companies who are subscribers to the Hudson Institute and who support ongoing work within that group.

That is an exhaustive compilation of global modeling. There aren't any other global models widely available, and I don't know of any others currently underway. Where do they leave us with respect to any images we might have of the future? Presumably there has to be some consensus if this kind of effort is to provide any improvement over the current situation. Let me excerpt a set of quotes from each of these studies in the area of food production to illustrate the points of view, the conclusions, and the recommendations which have come up within each of these pieces of research.

The Forrester model was general in nature. It did not focus on food as a specific discrete limit, but rather looked at it as one of a large number of interchangeable, interactive limits. I guess the viewpoints of the Forrester model might be illustrated by this passage: "It is no accident or coincidence that throughout history a substantial fraction of the world's population has been undernourished and on the verge of starvation. [Many factors] regulate population so that population stays at the critical condition on the edge of starvation. In fact, a Malthusian thesis has been true and at work at all times. Population is regulated to the food supply. But thus far man has caused population to continue to increase by being able to push up the food supply. Increasing the total amount of food has done little in the long run to reduce the percentage of undernourished people. Instead, the larger the population generated by the increased food supply, the greater the total number of people who live under the threat of starvation."[1]

Forrester's work was essentially to open up a new area of analysis, and he did not tie his findings to specific policy recommendations for specific decision makers. He simply concluded, "It must be stressed that only strong pressures will bring exponentially-growing population and capital investment into balance with a fixed or even declining environmental capacity. The pressures can be tangible, like those from lowering emphasis on capital accumulation, or the pressures can come from social forces: coercion, legal controls, reduction of personal freedom, and war. Each of the possible pressures raises major issues of humanitarianism and human rights. The challenge is to decide the balance of pressures that will be effective and at the same time most acceptable."

Forrester worked out a number of scenarios within his model but in every case he found it difficult to sustain the current rates of population and economic growth much beyond the year 2000. He found in his model that the most likely outcome was one in which population and economic growth stopped and then began a rapid decline because they had overshot important limits.

In our work we also did not focus on agriculture as a specific and separable problem, but we went into more detail than Forrester. We pointed out that half the world's land was already under cultivation, that fertilizer was in the process of reaching declining returns to scale, and that water shortages loomed in many areas. We then set out a set of changes in the behavior of the world system which would produce a relatively attractive outcome. These were not pointed to specific decision makers, nor did we go into the question of the political organization of these changes, whether they should come about in a decentralized or a centralized fashion. To give you an illustration of what could happen in the world in order to produce an alternative to overshoot and collapse: birth rate set equal to death rate in 1975, investment set equal to depreciation in 1990, resource consumption per unit of industrial output reduced by a quarter of its 1970 value, more emphasis on services and education, pollution generation cut by 25%, food production subsidized so those who cannot afford to buy their food can be well nourished, special emphasis on restoring soil fertility and halting erosion, average lifetimes of industrial capital increased. All of these rather drastic changes left us only with a population at current levels, about four billion people, and with a per capita income of $1800 per year. That's half the United States standard today, but three times the present world average, and roughly comparable to what Europe as a whole is experiencing. That left us also with food per capita at about two and a half times the present world average, though still significantly less than what we have in this country today.

We did not get into distributional issues because our model was not regionally disaggregated. We did suggest, though, that stopping growth need not imply necessarily that all regions of the world would stay at their current relative situation. Material growth could stop overall, while the richer parts of the world slowly declined and the poorer parts of the world slowly caught up. We did point out that if even a 15-year delay would be incurred in these changes, the kinds of options open to us would be very much less attractive.

Mesarovic and Pestel, given the increased detail of their model, were able to go into greater detail and to come up with somewhat starker forecasts. They said about food, "We have analysed the global food problem with our world model, and our analysis indicates that the historical pattern of development will make the food supply situation increasingly worse. Since the present situation is already producing catastrophic crises . . . , any further aggregation of the problem can only be regarded as apocalyptic."[2] They recommended a global approach to the problem, investment aid rather than commodity aid, balanced economic development for all regions, an effective population policy, and worldwide diversification of industry leading to a truly global economic system. They also went on to add that the strains on the global food production capacity would be lessened if the eating habits in the affluent part of the world changed to become less wasteful.

The Bariloche effort began from a different viewpoint and came up with a correspondingly and strikingly different set of conclusions. Said they, "According to FAO estimates, the quantity of food currently produced is sufficient to satisfy the needs of everybody in the world. It is also well known that, for the time being, physical limits do not restrict the production of food; only 43% of potentially arable land is being used, and even using conservative estimates, yields are much lower than those theoretically possible."[3] Then they went on to ask rhetorically, "If there are no physical limits, why is a high proportion of the world's population undernourished?"[4] The answer they suggested, in contrast to the picture that emerged from *The Limits to Growth*, lies in distribution. "The true causes of hunger have their roots in sociopolitical factors, at both the international and the national levels. Especially important in underdeveloped countries are local factors of social and political organization that hinder the equitable distribution and production of food. . . . It is evident that, if the sociopolitical factors that hinder production and distribution of food were modified, the problems of hunger and undernourishment could be solved."[5] They went on in their model, then, to focus primarily on social-political variables rather than the kinds of physical variables which had been the subject of the earlier studies. "The results of the model set out in the previous chapter demonstrate that if the policies proposed here are applied, all of humanity could attain an adequate standard of living within a period of one generation."[6]

Linnemann, in his Dutch work, came up with a different statement of the problem: distribution is not the issue, but rather, "the central issue in the world food problem is: how to raise production and consumption levels in the developing countries at a higher rate than the present one."[7] They came down essentially with a global, social-political type of solution coupled with economic measures. "The solution can and should come by way of a coordinating world agricultural policy, a policy that will compel all countries to formulate their national agricultural policies with due regard to the interests of others."[8] Given those circumstances, the Linnemann group was under the impression that the world population could be fed by the year 2000, but they noted very serious ecological and environmental constraints that had to be dealt with.

Finally, Leontiev says in his input-output analysis, "It is clear . . . at least with respect to the major food staples, the doubling and trebling of land productivity is a realistic technical and organizational possibility. . . . This task clearly involves substantial investment . . . and the success of the new technological revolution . . . will depend to a large extent on land reform and other social and institutional changes. . . . [But] if these conditions are met, then the formidable task of feeding the rapidly increasing population of the planet, and of improving diets in all regions of the world would be fulfilled."[9]

Kahn, working without the benefit, or without the hindrance, of a computer model, came up with quite a different point of view. ". . . Except for occasional regional fluctuations caused by natural disaster, . . . the long-term prospect is for adequate food supplies. By 'adequate', we mean both an increasing amount of food per capita and an improving nutritional balance in the countries of the world currently deficient in either of these respects. Indeed, within 200 years, we anticipate that — if desired — it will be possible to increase world food consumption to the level of the United States today."[10] And, within 200 years, Kahn was anticipating a population of something between 15 and 30 billion people, four to eight times current levels. He went on to deal with the question proposed by Mesarovic and Pestel and some of the other studies, of taking from the rich to give to the poor. "It has been argued that Americans should eat less meat and stop fertilizing their lawns and golf courses to make more food and fertilizers available to the poorer countries of the world; but, however noble the intentions, these policies are unlikely to have any measureable impact, much less any long-range significance. . . . There is no shortage of fertilizers or food; either can be bought if the funds are available. . . . About the only thing that self-restraint in consumption of meat and fertilizer would do is add to the propaganda that the rich are taking away from the poor — a position which we argue is in almost every way . . . contrary to the facts and counterproductive."[11]

We have here eight global models, each undertaken with a great deal of earnest and expensive effort, addressing ostensibly the same globe, and looking at the same issues, that is to say, how we can feed the world's people. Each of them comes up with rather different conclusions, ranging from Kahn's projection, on the one hand — that we can feed 30 billion people at levels like that of the United States today — to our projection, which says that we could feed perhaps four billion people at levels substantially below current American standards — to the projections by Mesarovic and Pestel which began under most circumstances to project a high and rapidly accelerating death rate in many areas of the world from malnutrition before the end of the century.

CHOOSING A MODEL TO GUIDE DECISION MAKING

The question comes, how do you pick? How do you choose which of these models is the appropriate basis for your decisions? As I said at the opening of my remarks, all of us have some global model in our minds, because all of us are involved every day in making decisions that have long-term implications: we vote for people who make them, we buy products from people who make them, and therefore some kind of image of the future has to lie behind those actions. In most cases it is a global model which says essentially that the future will be like today. As I said, that is probably the one thing that we can rule out as a possibility. Now one needn't go to global models; one can go to the intuitive models which are put forward by politicians, and to shorter-term models as well, and still find apparent contradictions.

Once again one asks how do you pick? I think it's important at the outset to recognize that there is no objective way of picking. In the area of global modeling we're still at the very beginning of a long-term program of development, and in some sense even asking how to pick the right global model is something like the alchemists of old sitting around and asking how to pick the right philosopher's stone. It fails to even anticipate some of the most profound directions that the field is going to take.

I'm going to list a set of questions; I'm not going to answer them. I'll acknowledge at the outset that the questions themselves would not be accepted by everybody as appropriate, much less the answers. I provide them simply as a guideline and as an index of the state of development of the field. First of all I would ask, what is the time horizon of the model? Over what time period is the person trying to generate some useful information? Short-term models are by their nature very different from long-term models. They can ignore many of the important longer-term interactions. Is the model static or dynamic? Is it trying to project an image, an instant in time, or to project the evolution of society over time? Does it reproduce history? What's the boundary of the model? Does it include physical, social, and biological interactions, or does it hold many of those constant, or treat them as exogenous and focus on a specific set? We have always the choice between wide, shallow models and narrow, deep models (narrow, deep models being ones which have an enormous amount of detail on, for example, the economic sector, and no information whatsoever about demographic, biological, agricultural, and other relationships). Contrary to popular belief, computers don't give us the possibility of putting everything into the model. We run up against not only computer time limits but comprehension limits, and very quickly these models grow so complex that they're of no more assistance to us than the real world in understanding our options.

What image of man underlies the modeling effort? Is man assumed to be an economic, price-oriented optimizer, or someone quite short-sighted, with deficient information, who tries to attain satisfaction along a number of rather limited, and typically non-economic, goals? Is man globally cognizant and concerned, or egocentric and quite preoccupied with current events? Is man one who can gain mastery over all the other forces of the world, or is man rather one of a large number of species which are destined forever to cohabit this earth under subjugation of many biological and physical laws?

What comes out of the model? How does that interact with the mind of the decision maker? Are there any surprises in the analysis, or does it simply illustrate what the analysts had assumed to be the case before they went into the project? It's useful in this case, I think, to ask yourself rhetorically what are the conclusions from this effort that would further the short-term political, psychological, or financial goals of those who are involved in the development of the model. I somehow respect much more models which seem to mandate actions which are not in the apparent best interests of the people who put forth the analysis.

Is the model expressed in dollar terms or in physical terms? Are the relationships causal or correlational? Is the model restricted to those elements on which we have a great deal of data, or did the analyst first try to decide what was important and then look around for the best way of estimating its effects? What are the sensitivities of the model to changed assumptions? What are the verbal statements of the key theories in the model? Many models are ostensibly quite complex — take the Linnemann model, for example, with 106 countries — but what you find is that many equations there are simply manifold replications of trivial assumptions. One can take a very trivial assumption about the consumption process in a country, replicate it 106 times, once for each country, and one still has a trivially simple assumption. Alternatively, one can take the consumption process for one country and make 106 statements about it and come up with something which is conceptually quite rich.

Finally, and I think at this stage most importantly, is the analysis objective? Can people outside the original group get their hands on the equations? Can they replicate the results? Can they test the model's sensitivity to changes? Can they extend the model to see how it might respond under different circumstances? Until I can lay my hands on the equations which have produced someone else's results, I will not accord that person any credit for undertaking a scientific job of investigation.

That list is certainly incomplete, but it does illustrate what is still to be resolved. Some people may throw up their hands at this stage and say that a field which is in such a state of disarray simply should be ignored and should cease to be the focus of any concerted effort. I think another viewpoint is appropriate. I'd say rather that in the field of global modeling, in creating these backwards memories, we're moving off into a program of development which is going to take many decades, but which will, over time, begin to generate the basis for more effective anticipation of what's going to happen in the future.

CONCLUSION

I find the field of global modeling to be quite exciting. If you stop to think about it, the frontiers which have challenged us over the last two hundred years of this country's existence are now mainly closed. The new lands are settled, many of the new fields of science are well mapped out. If I look ahead to think where exploration is still possible, three fields occur to me: one is outer space, one is the human mind, and the third is the distant future. Computers, working with man, are going to be helpful in each of those areas, but it's really in the exploration of the future that we come down to the computer as the essential tool. Man unaided by machine logic can explore outer space, and we have tools that can penetrate into the cerebral cortex, but we have no other way of getting our hands on the future, the distant future, except through the use of computers to trace out the interactions of the very large numbers of factors which are involved in bringing social evolution.

We are never going to be able to predict the future precisely, but I think the case has been made already that there is enough momentum inherent in the operation of our social, institutional, and physical relationships to allow us to trace out essential tendencies of society far into the future. The enormous range of problems that confront mankind at the moment suggest to me that it is extremely important to do so. In closing I might paraphrase Aristotle. He said, "Those of us who ignore the past are destined to relive it." I think I would add to that, "Those of us who ignore the future may lose it."

FOOTNOTES

1. Jay W. Forrester, *World Dynamics* (Cambridge, MA: Wright-Allen Press, Inc., 1971), pp. 27–8.
2. Mihajlo Mesarovic and Eduard Pestel, *Mankind at the Turning Point* (New York: E. P. Dutton and Co., Inc., Reader's Digest Press, 1974), pp. 115–6.
3. Amilcar O. Herrera et al., *Catastrophe or New Society? A Latin American World Model* (Ottawa: International Development Research Centre, 1976), p. 55.
4. Ibid.
5. Ibid.
6. Ibid., p. 107
7. Hans Linnemann, *Population Doubling and Food Supply* (Amsterdam: Economic and Social Institute of the Free University, 1974), p. 12.
8. Ibid., p. 16.
9. Wassily Leontiev, Anne Carter and Peter Petri, *The Future of the World Economy: A Study on the Impact of Prospective Economic Issues and Policies on the International Development Strategy* (New York: United Nations, 1976), pp. 20–1.
10. Herman Kahn, William Brown and Leon Martel, *The Next 200 Years* (New York: William Morrow and Company, Inc., 1976), pp. 107–8.
11. Ibid., pp 114–5.

REFERENCES

1. Forrester, Jay W. *World Dynamics*. Cambridge, MA: Wright-Allen Press, Inc., 1971.
2. Meadows, Donella H.; Meadows, Dennis L.; Randers, Jorgen; and Behrens, William W., III. *The Limits to Growth*. New York: Universe Books, 1972.
3. Meadows, Dennis L., and Meadows, Donella H., eds. *Toward Global Equilibrium: Collected Papers*. Cambridge, MA: Wright-Allen Press, Inc., 1973.
4. Meadows, Dennis L., et al. *Dynamics of Growth in a Finite World*. Cambridge, MA: Wright-Allen Press, Inc., 1974.
5. Herrera, Amilcar O., et al. *Catastrophe or New Society? A Latin American World Model*. Ottawa: International Development Research Centre, 1976.
6. Mesarovic, Mihajlo, and Pestel, Eduard. *Mankind at the Turning Point*. New York: E.P. Dutton and Co., Inc., Reader's Digest Press, 1974.
7. Mesarovic, Mihajlo, and Pestel, Eduard. *Multilevel Computer Model of World Development System*. 6 vols. Luxembourg: International Institute for Applied Systems Analysis, 1974.
8. Linnemann, Hans. *Population Doubling and Food Supply*. Amsterdam: Economic and Social Institute of the Free University, 1974.
9. Leontiev, Wassily; Carter, Anne; and Petri, Peter. *The Future of the World Economy: A Study on the Impact of Prospective Economic Issues and Policies on the International Development Strategy*. New York: United Nations, 1976.
10. Cole, H.S.D.; Freeman, Christopher; Jahoda, Marie; and Pavitt, K.L.R., eds. *Models of Doom: A Critique of the Limits to Growth*. New York: Universe Books, 1973.
11. Kahn, Herman; Brown, William; and Martel, Leon. *The Next 200 Years*. New York: William Morrow and Company, Inc., 1976.

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